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Urban Green Space: Mitigator or Multiplier of Inequality in the Denver Metropolitan Area?

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Urban Green Space:

Mitigator or Multiplier of Inequality in the Denver Metropolitan Area?

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by

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Abstract

Studies have shown that communities of color and low-income populations are likely to live in neighborhoods that lack access to quality green spaces, unable to directly benefit from the environmental, recreational, and cultural services they provide. The goal of this research was to determine if the green space inequality patterns seen globally and nationally exist in the Denver Metropolitan Area. Using an existing green space dataset, ecosystem services fieldwork, GIS digitizing, and bivariate correlation analysis I uncovered numerous green space inequalities based on proximity, acreage, and quality. Key findings included 1) Lakewood's Hispanic and less-educated populations have relatively little access to green space for acreage and proximity; 2) Denver's Hispanic, Black, and lower-income populations have slightly better access to green space than White and higher-income populations; 3) Aurora's White populations have much better access to green space than its Hispanic, Black, and Asian populations; 4) for green space quality, as defined by ecosystem services, Lakewood and Aurora appear to have the least amount of disparity, and the most striking result was the positive relationship between the ecosystem service index score and White populations in Denver; 5) Denver neighborhoods with a high concentration of females have statistically less access to high quality green spaces than males; 6) Lakewood's ecosystem services scores are the lowest, which means that its green spaces provide relatively fewer benefits than Denver or

Aurora; and 7) Aurora's Asian populations appear to live in neighborhoods that have the highest quality green spaces in all of Aurora.

Using equity mapping techniques and spatial statistics I identified three clusters of green space inequality and focused a critical urban geography lens on its green spaces and surrounding neighborhoods. I outlined their histories and examined factors that led to these spatial disparities based on green privilege, environmental justice, and green gentrification. I used environmental justice theory, in the form of distributional, procedural, and recognitional justice to promote solutions to the wicked problem of green space inequality. Finally, I proposed a new conceptual framework for understanding the push-pull dynamics and multitude of factors that can either mitigate or multiply green space equality.

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My journey as a geographer began in the Department of Geography at New Mexico State University. It's where I first learned about GIS and remote sensing, the complexities of human-environmental interactions, conservation, ecosystem services, and most importantly where I learned how to read a landscape from one of the last Berkeley school adherents, Dr. Jack Wright. I would like to thank each of the faculty members there who pushed me into this life-long pursuit of geographic knowledge.

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Introduction

Cities across the planet are grappling with a multitude of intractable social and environmental problems: lack of affordable housing, deteriorating infrastructure, insufficient transit, food insecurity, climate change, drinking water crises, pollution, natural disasters, and more. Urban sustainability has emerged as a remedy to cut through the Gordian knot. Interest comes from multiple scales. Global institutions such as the United Nations and the World Health Organization are promoting major initiatives; Goal 11 of the United Nation's Sustainable Development Goals is to is to "Make cities inclusive, safe, resilient and sustainable". In the absence of national guidance, regional planning entities in the U.S. are facilitating sustainability initiatives such as public transit through public-private partnerships, data sharing, and grant making. Local communities are where the "rubber hits the road", where decisions are made on land use planning, infrastructure, public safety, and the like.

Over the last couple of decades, urban parks, green space, and other nature-based amenities have been promoted as a key component of urban sustainability to address a range of environmental and social ills – from climate change to urban blight to obesity. Indeed, urban green space provides numerous ecosystem services, i.e. environmental, social, health, and economic benefits to its local users. Green infrastructure, such as urban forests and riparian corridors, supports biodiversity, regulates air temperature and quality, and protects drinking water. Urban parks and open space provide recreational opportunities for residents which are linked directly to health, well-being, and cultural benefits. Urban green spaces make cities vibrant and desirable places to live.

However, recent studies suggest that these common resources are not always provisioned evenly across cities or regions. Access to and use of parks are often stratified along socio-demographic lines such as income, race, age, and gender. Moreover, residents are often mismatched with green space they don't use or want – posing serious social challenges. The reasons for this are complex and often involve racially charged histories of land use and zoning practices. Environmental justice advocates, community organizers, and academics have been at the forefront of the debates, noting the uneven patterns of green space and potential pitfalls of sustainability "greening" programs.

At the other extreme, urban green space can become an enclave of environmental privilege. Some U.S. cities appear to be actively cultivating green space luxury for the creative classes flocking to their hip and "sustainable" downtowns. Green gentrification is the process by which cleaning up blighted neighborhoods or providing green amenities such as parks, greenways, and riverfront walks increases property values and capital investment, pushing existing communities out. Although green gentrification is on the rise across the U.S. it is starting to be contested. However, more research is needed to understand the scope and magnitude of green space inequality – where it happens and why. As complex and dynamic as these inequalities are, we need to be able to identify the push-pull dynamics and multitude of factors that can either mitigate or multiply green space equality[1]

Problem Statement

Urban parks make cities ecologically, socially, and economically vibrant – and yet they are not provisioned evenly in cities. Communities of color and low-income populations are especially likely to live in park poor neighborhoods, unable to directly benefit from the services they provide. Park access has emerged as a compelling environmental justice concern. However, very little research has been undertaken to determine if other types of green spaces follow the same allocation logic as parks. More research is needed to understand the disparities and dynamics of access to all urban green space, and especially the services they provide to users. Identifying these disparities and explaining where they come from can help guide local planning efforts and international initiatives to assist in appropriately provisioning urban green space.

The focus of this research is on spatial inequalities of urban green space patterns in the Denver Metropolitan Area. The main research agenda was to analyze green space quantity (access and proximity) and quality (field-based ecosystem service index) for three municipalities through the lens of socio-demographic census data. A mix of quantitative and qualitative methods were used. I visited 160 green spaces across the study area, collecting in situ data on ecological and cultural features, as well as user activities. The main data product was a unique ecosystem services index, which was a primary variable for bivariate correlations with various socio-demographic variables.

[1] See Appendix A for more information on the terms "inequality" and "inequity".

Finally, planning and historical documents, as well as "grey literature", were analyzed to uncover the institutional arrangements and management regimes which may have led to the current pattern of green space distribution. Research has found that White and higher income populations have access to better and more green space than communities of color and lower income populations. I was not surprised to discover that municipalities produced different results. I was surprised to find that even the most diverse city, with only 47 % White population, was not immune to green space inequality.

Literature Review

Introduction

Four analytical perspectives are relevant to understanding urban green space disparities and associated social and ecological features. They are 1) *environmental justice*, including how this body of practice has been incorporated into a body of research by geographers; 2) *urban green space and ecosystem services*, including ecological economics and common pool resource theory; 3) *just sustainability*, which posits a more equity-focused definition of urban sustainability; and 4) *critical urban geography and urban planning*, which helps illuminate current urban-environmental pitfalls such as ecological gentrification.

Environmental Justice and Urban Park Research

The environmental justice movement in the U.S. has evolved over the decades from investigating issues of point pollution located in rural poor and minority communities to the unequal distributions of amenities in urban areas. In the late 1970s, the Love Canal chemical waste exposures and subsequent dislocations were major news stories. By the

1980s, environmental justice research and practice began to document minority community's disproportionate proximity and exposure to environmental hazards. Bullard's (1990) pioneering book *Dumping in Dixie: Race, class, and environmental quality* daylighted the racial components of illegal dumping practices across the southern U.S. In 1982, one of the first national protests of hazardous waste was triggered in Warren County, North Carolina, one of the poorest counties in the state (Bullard 1990). The state government wanted to create a burial site for PCBs in the town of Afton, which was 84 % African American, but the dump trucks were met with demonstrations and protests. Although they were ultimately not able to stop the toxic landfill from being built, the protests drew national media attention and it is considered to be the first major milestone in the national movement for environmental justice (National Resources Defense Council 2020).

Environmental justice leaders were successful in the 1990s with gaining the attention of the Bush and Clinton administrations. In 1992, the Bush Sr. administration established the Environmental Equity Working Group in the EPA and initiated federal meetings on environmental justice issues with community leaders. In 1994, President Clinton issued Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The order directed the federal government to make environmental justice concerns part of federal decision-making processes (Department of Energy 2020). Since the early 1990s national environmental justice strategies and policies have been housed in the Environmental Protection Agency, although during the Trump Administration, the agency was largely stripped of its environmental justice emphasis.

Recent environmental justice research and practice has widened its scope from a focus on environmental burdens to include the distribution of goods and amenities (Boone et al. 2009). An early legal precedent for this type of analysis comes from a 1971 ruling of the U.S. Fifth Circuit court. The appellants in the case were Black citizens of Shaw, Mississippi who alleged that the town provided municipal services such as street lighting and paved roads in a discriminatory manner (U.S. Court of Appeals 1971). It was a landmark ruling because it established the legal precedent that if a community elects to provide a public service, it must be made equally accessible to all citizens (Marcuse 1978; Sister et al. 2010).

Geographers have been at the forefront of this research, due to the spatial nature of these emerging environmental justice concerns. According to Sister et al. (2010), the uneven distribution of public resources are ultimately environmental justice struggles, and "differential access to urban public facilities that privileges one group and disadvantages another may also constitute environmental injustice" (231). Thus far, research on the allocation of urban amenities have focused on vegetation cover (Pedlowski et al. 2002; Heynen, Perkins, and Roy 2006; Landry and Chakroborty 2009; Schwarz et al. 2015) and the placement of parks (Low, Taplin, and Scheld 2005; Wolch, Wilson, and Fehrenbach 2005; Boone et al. 2009). These studies suggest that the distribution of environmental amenities favor White populations and affluent communities. Accordingly, people of color are likely to live in vegetation- and park-poor neighborhoods (Boone et al. 2009; Byrne and Wolch 2009). This has led to a variety of research angles to understand how and why.

Two review articles have given shape to this new agenda. Boone et al. (2009) assessed several environmental justice concerns with respect to urban parks: definitions of "just distribution"; the political and historical factors that influence park distribution; park neglect, park safety, and unintentional exclusionary practices such as redlining[2]. The article culminates in a park distribution and access analysis of Baltimore, Maryland. Using a novel park service area approach that measures park congestion, they found that more Black populations were within a quarter mile of parks, but White populations had access to far more park acreage. This means that Black populations had access mainly to highly congested parks. Through historical research, they found that segregation ordinances and policies of the Baltimore Parks and Recreation Board led to these spatial injustices.

Much like the Boone article, Byrne and Wolch's (2009) review focused on environmental justice and public parks but added several theoretical considerations. Their review starts with a list of themes most often studied in geographic and geography-adjacent disciplines: the history and ideology of parks; park utilization; the potential of parks to foster urban livelihoods; the ecosystem service benefits of parks; how parks benefit the health and well-being of urban residents; and leisure and ethnicity theories of

[2] This dissertation uses the term "urban green space", or "green space" for short, to describe publicly accessible land within a municipality's territory that has been set aside for recreational, environmental, or engineering purposes (more on this in the next chapter). The term "park" is used if it has already been established by another author, or I am referencing a specific park.

park use. Several theoretical perspectives endemic to geography were then applied to park use.

Drawing on cultural landscape and political ecology theory, the authors draw our attention to historical, social, and political-economic processes that create “park spaces”. Tracing the evolution of parks in Europe and the U.S. – from the City Beautiful Movement onward – they talk about parks as “spaces of exclusion”, and how park use varies widely by race. One of their main arguments is that racial groups exhibit very distinct preferences for why they visit and what they do at parks. Black populations evidently enjoy more sociable, formal, sports-oriented activities; whereas White populations are said to be interested more with individualistic pursuits such as jogging and prefer secluded settings (Gobster 2002). The main product of their review was a conceptual model that shows connections among park use, user perceptions, and park space. Their key message is that understanding why people use or don’t use certain parks is just as important as whether they have access to them. This highlights the need for a more nuanced understanding of parks, especially one that looks at the underlying quality of parks.

Urban Green Space and Ecosystem Services

Urban green space is defined as a piece of publicly accessible land within a municipality’s territory that has been set aside for recreational, environmental, or engineering purposes. Urban green space types fall on a “green-to-grey” continuum and include land such as open space, city parks, green infrastructure, community gardens, tree rows, and vacant lots (Figure 1).

Open space Green belt Greenway	Urban forest Wetland Riparian corridor	Retention ponds Green roofs Bioswales	City parks Community gardens Schoolyard/Campus	Tree row Alleyway Roadside	Brownfield Vacant lot

Green to Grey Continuum

Figure 1 – Urban green space types on a "grey-to-green" continuum

Many environmental, social, health, and economic benefits are provided by urban green space. Green infrastructure – such as riparian corridors, urban forests, and storm water catchment systems – supports biodiversity (Elmqvist et al. 2014), regulates air temperatures and quality (Bowler 2010), and protects drinking water (Bolund and Hunhammar 1999). Urban parks and open space provide recreational opportunities for residents, linked directly to health, well-being, and cultural benefits (Lee and Maheswaran 2011). Urban greenery and biological diversity is associated with wealthy neighborhoods, referred to as the "luxury effect" (Hope et al. 2003). Ultimately, urban green space makes cities ecologically and socially vibrant places to live. Nevertheless, many of the amenities provided by green space remain undervalued by the very populations that use them every day (Goulder and Kennedy 1997; Kumar 2010).

Ecosystem services are the benefits that people derive from the natural environment (Costanza et al.1997; Daily 1997). These include *provisioning* services such as food, fresh water, timber, and medicinal plants; *regulating* services such as climate and air quality regulation, water purification, and flood, drought, and disease regulation; *supporting* services such as biodiversity, soil formation and nutrient cycling that underlie the previous two services; and *cultural* services such as recreational, health, and aesthetic benefits (Millennium Ecosystem Assessment 2005). The ecosystem services concept has been used for numerous environmental causes, from supporting conservation efforts to developing carbon markets. Some of the most influential analyses have been done at the state or continental scale emphasizing natural capital (Costanza et al. 1997; Costanza et al. 2014) or their contribution to global biogeochemical cycles (Millennium Ecosystem Assessment 2005). Urban ecosystem services represent a unique, yet understudied, research topic (Bolund and Hunhammar 1999; Pataki et al. 2011; Gómez-Baggethun et al. 2013; Andersson et al. 2014).

One of the greatest prospects of using the ecosystem services concept in urban green space research and practice is its ability to articulate the natural environment's ecological, social, and economic benefits to a concentrated number of people (Daniel et al. 2012). As public space, urban parks and green infrastructure are visible and interacted with daily in the urban landscape. Many studies have pointed out the public health benefits of green space, including psychological well-being (Chiesura 2004), stress management (Ulrich et al. 1991), physical activity (Diez Roux et al. 2007) and obesity mitigation (Timperio et al. 2005). Richard Louv's landmark book *Last Child in the Woods* (2005) offers compelling evidence that children who lack access to green space such as parks suffer from a range of behavioral problems – a condition he describes as "nature deficit disorder". Urban ecosystem services clearly support human well-being, yet because the benefits they provide tend to be outside conventional markets, people rarely recognize their value.

Market valuations do exist in the ecological economics literature. A recent salient example of urban green space valuation was undertaken for iconic Central Park in New York City (Sutton and Anderson 2016). Using developable real estate as a proxy measure of ecosystem services, the authors found that one hectare of the park was worth $70 million dollars annually, for a park total of $500 billion annually. This number, although astronomical, does not even consider the complex suite of services provided by Central Park (McPhearson, Kremer, and Hamstead. 2014). The park is a public space, offering many things to many people. A key challenge is to acknowledge the value of urban ecosystem services while managing them as public goods (Fisher et al. 2008).

Two important concepts in economic and political theory which relate to urban ecosystem services are “excludability” and “rivalry”. Excludability refers to whether people can be prevented from consuming or accessing a good or service. Rivalry refers to whether a good or service can be used by only one person at a time, and whether it diminishes after use. Goods and services which are both rival and excludable are private goods; we are most familiar with these types as they make up most of our daily market interactions. In contrast, pure public goods are neither excludable nor rival; they can be used by multiple people at once and are not diminished after multiple uses. There are many permutations of excludability and rivalry – from market goods to purely public goods (Table 1). Most ecosystem services fall into the non-excludable, non-rival category and are therefore usually not bought or sold (Costanza et. al 2014). They are outside the market, free from the laws of efficient allocation (Daly and Farley 2011).

Common pool resources, known as "the commons", are nonmarket goods. They are non-excludable and rival resources such as fresh water and grazing pastures. Research on the commons is usually applied to open access systems such as pastures, fisheries and forests (Hardin 1968; Ostrom 1990). Recent studies have looked at urban permutations of the commons: urban public space (Blackmar 2006; Foster 2011; Nemeth 2012; Stavrides 2016); dog parks (Matisoff and Noonan 2012); community gardens (Colding and Barthel 2013); and urban lakes (Nagendra and Ostrom 2014).

Table 1 - Rival-Excludability box

	Excludable	**Non-excludable**
Rival	Market Goods and Services • Food • Clothing • Cars • Gasoline	Common-Pool Resources • Fresh water Open Access Regimes • Fishing grounds • Open grazing pastures
Non-rival	Club Goods • Information • Movie theaters • Private parks	(Pure) Public Goods • Lighthouses • Over-the-air television Ecosystem Services • UV protection by the atmosphere • Storm surge protection provided by mangroves • Aesthetic, spiritual, and health benefits of hiking

Although not always adhering strictly to the non-excludable/rival category that defines a common-pool resource, these articles demonstrate the usefulness of thinking about urban green space as a commons. A key insight offered by Colding and Barthel (2013) is that by conceptualizing green space as commons, we can foster a culture of environmental stewardship and civic participation in urban land management that may help bridge the human-nature gap in cities. Indeed, designing, planning, and managing urban green spaces for human health and well-being requires them to be managed thoughtfully and sustainably (McPherson et al. 2014). In order to provide these common spaces, and their critical ecosystem services reliably over time, cities will need to figure out how to balance their environmental qualities with the social needs of its citizens.

Just Sustainability

Julian Agyeman's book Just Sustainabilities (2013) provides the theoretical background for a new way of conceptualizing sustainability. Most sustainability theory and practice over the last 30 years has focused on the environment (World Commission on Environment and Development 1987; Goodland 1995; Adams 2006). By foregrounding the environmental aspects of sustainability and various "green" solutions, these early writings often framed the sustainability debate as separate from social and cultural realms. Building on core environmental justice research (Bullard 1990; Agyeman, Bullard, and Evans 2003), Agyeman's thesis is that genuine sustainability can only be achieved if we highlight social needs and economic opportunity questions in the debate. Accordingly, a more equity-focused definition of sustainability is needed – one that includes well-being, equity, justice, and living within our ecosystem limits.

Nearly all economists agree that economic growth is paramount. However, not all agree that growth is compatible with improving human well-being and quality of life. Research communities as diverse as Marxists and ecologists argue that growth under capitalism has hit its apex. Even if growth rates could be sustained, there is no evidence that this would automatically translate to more well-being for all. For example, the Gross

Domestic Product (GDP) of a country's economy is a notoriously poor indicator of a country's overall health and well-being (Kubiszewski et al. 2013). An oil spill will increase GDP due to clean-up costs but will undoubtedly diminish environmental health and human well-being. This conventional economic index misrepresents the true pulse of a society; as Robert F. Kennedy said, "…[GDP] measures everything in short, except that which makes life worthwhile". An array of alternative indicators have been developed to counter GDP. Indices such as the Genuine Progress Indicator (Lawn 2003) and Human Development Index (Anand and Sen 1994) combine economic variables with health, education, and social variables – as well as environmental conditions – to uncover a more robust characterization of human activity. These alternative indicators pay much closer attention to inequality and recognize that traditional measures like GDP can be misleading.

According to Agyeman (2013), justice and equity can best be thought of in terms of recognition, process, procedure, and outcome. Justice is concerned with what is morally right in society and is known as "the first virtue of social institutions" (Rawls 1971). Justice is a complex subject with profoundly differing philosophical and ideological perspectives: e.g. utilitarian, egalitarian, libertarian. Agyeman takes a multidimensional approach to justice, locating it within a matrix of institutional responsibilities (Schlosberg 2007) and personal capabilities (Sen 2009). Recognition pertains to how groups are treated in a society and how some people are subjugated for arbitrary reasons such as gender and color. Process and procedure pertain to laws and governance, i.e. people's participation within the legal system, who makes decisions, how they are made, and the institutions that bind them. Outcomes pertain to the material results of justice (or injustice) in a society. Missing one or more of these dimensions, equity may be unattainable, or at least very difficult to achieve. Ultimately, equity requires robust institutions based on justice for people to flourish.

The just sustainabilities concept integrates justice and the environment into one framework with the goal of living within our ecosystem limits. Since the 1960s, interest in environmental issues has grown. Rachel Carson's *Silent Spring*, the Ehrlich's *Population Bomb*, and the Club of Rome's *Limits to Growth* galvanized a generation and launched the Western environmental movement. As these books observed, natural resources on our planet are fragile and finite. When faced with resource scarcity in the past, societies either perished or imported goods and materials from distant lands. With globalized consumption patterns and the sheer number of humans on the planet, stocks of material resources and arable land are dwindling. In the 1990s, a method was developed for measuring environmental limits by quantifying our "ecological footprint" (Wackernagel and Rees 1998). Their methodology uses an ecological accounting system to measure biocapacity by comparing productive land area used for food, fiber, etc. to the productive land available. Although not without criticism, this research was an important step in quantitatively determining the impact of human populations on the planet. More recently, several international teams of Earth system science researchers have furthered our understanding of global change and ecological boundaries.

According to Steffen et al. (2011), the relative stability of the Holocene epoch which has provided an accommodating global environment for *Homo sapiens* over the last 12,000 years is potentially giving way to the Anthropocene. This proposed new epoch, characterized by human manipulation of global biogeochemical cycles and ecologically destructive land-use changes, may be pushing Earth's systems across thresholds from which they may not be able to recover. Nine "planetary boundaries" have been proposed to represent a safe supply of the regulating and supporting Earth system services (Rockstrom et al. 2009). These processes – climate change, stratospheric ozone, ocean acidification, nitrogen and phosphorous cycles, biodiversity, land-use change, and global freshwater use – all have thresholds which, if crossed, could lead to undesirable environmental changes. Rockstrom and collaborators estimate that four of the boundaries have already been crossed: climate change, the nitrogen cycle, biodiversity loss, and land use change (Steffen 2015).

A criticism of Anthropocene and planetary boundary research is that it does not fully develop the underlying social aspects of our rapidly changing world. Then Oxfam researcher Kate Raworth (2012) answered this critique by extending the environmental ceiling hypothesis that Rockstrom et al (2009) outlined to include a social foundation consisting of human necessities such as education, jobs, gender equality, and health. Between the upper environmental boundary and lower social boundary lies a doughnut shaped area representing an environmentally sound and socially just space for humanity. Inside the doughnut is where inclusive and sustainable economic development can thrive. The framework draws together human well-being and justice through an ecological economics perspective that seeks to expand our notion of sustainability. The environmental aspects of sustainability are clearly important, but as Agyeman's concept of just sustainability, along with Raworth's analysis, shows that equity and justice are just as important.

Critical Urban Geography and Spatial Justice

For decades, geographers have used critical lenses to view cities. From the ashes of the "quantitative revolution" of the mid-20th century, urban geography has turned increasingly to theories of political economy to explain the causes and effects of urban morphology and resource distribution. Using Marxist theories such as dialectical materialism and capital accumulation, David Harvey's pioneering book *Social Justice and the City* (1973) posited new directions for geographical study. The rationale for the book was to show how liberal perspectives on the city and urban planning can be used as antidotes to social problems. He looks at income inequality among poor and rich neighborhoods and how spatial organization of the city informs political, social, and economic processes. He uses access to services as a prime example. Since at the time of his book, higher paying jobs tended to be in suburban areas and poorer residents tended to live in the city core, transportation costs were a deterrent for poor residents to gain high paying jobs. In an extended section on social justice and spatial systems he explores the legal and economic notion of just distribution with what he calls "territorial distributive justice'.

> The first step in formulating a principle of territorial distributive justice lies in determining what each of the three criteria—need, contribution to common good, and merit—means in the context of a set of territories or regions. Procedures may then be devised to evaluate and measure distribution according to each criterion. The combination of the three measures (presumably weighted in some way) provides a hypothetical figure for the allocation of resources to regions. This figure can then be used, as happens in most normative analysis, to evaluate existing distributions or to

> devise policies which will improve existing allocations. A measure of territorial justice can be devised by correlating the actual allocation of resources with the hypothetical allocations. Such a procedure allows the identification of those territories which depart most from the norms suggested by standards of social justice: but this is not, of course, easy (101).

A few pages later, he clarifies the principles of social justice as applied to geography:

> The spatial organization and the pattern of regional investment should be such as to fulfil the needs of the population. This requires that we first establish socially just methods for determining and measuring needs. The difference between needs and actual allocations provides us with an initial evaluation of the degree of territorial injustice in an existing system (107).

Without getting too drawn into Harvey's neomarxism and concomitant socialist re-ordering of the city, I think this idea of territorial distributive justice is important and has been overlooked. The above principles can clearly be used to evaluate existing spatial distribution in cities, and they provide an early attempt at a normative theory of urban spatial organization.

Following Harvey's use of Marx to describe how cities concentrate capitalist modes of production, Neil Smith's work follows this line of inquiry. In *Uneven Development: Nature, Capital, and the Production of Space* (1984) he proposed that social relations of capitalist societies are translated into spatial forms. Uneven (spatial) development is thus a function of economics and the logic of capital markets, whereby development of an urban area is often followed by its underdevelopment, which in turn establishes the conditions of redevelopment. Smith is also known for his writings on gentrification (Smith 1979; Smith and Williams 1986; Smith 1996), which helped clarify that the driving force behind gentrification is in fact capital, not cultural or consumer preferences for nicer housing. According to Smith's rent gap theory, the main ingredient of gentrification is the disparity between the current value of a property and its potential value. It is this differential, this gap, which compels investors to renovate houses and neighborhoods, resulting in increased rents and property values.

Picking up from Harvey's call to urban distributive justice, Edward Soja's *Seeking Spatial Justice* (2010) is an extended foray into the practical and theoretical politics of urban space. Throughout the book, he examines the production of unjust geographies – e.g. segregation, social exclusion, "distributional inequality", "spatial discrimination" – under the regime of capitalist accumulation. He provides a recent history of social activism in Los Angeles that has been fighting against various urban restructuring processes. For instance, in 1996 the Los Angeles Bus Riders Union scored a major court victory over the city's Transit Authority to remap bus lines to better serve lower income neighborhoods. As touched on earlier, mobility and proximity to services and public goods can have a tremendous impact on people's relationship to the city (Harvey 1973). It's no surprise that *Seeking Spatial Justice* and Harvey (2012) dedicate major intellectual labor to how spatial inequalities end up blocking people's "right to the city"[3].

A critique could be made of spatial justice theory that it puts too much emphasis on the machinations of capital, and not enough on the underlying urban landscape. By

[3] This term comes from Henri Lefebvre, a French Marxist philosopher and sociologist active in the Paris during the 1960s. The English translation of his 1974 book *The Production of Space* (1991) has had a major influence on urban theory. Something that has animated Lefebvre, Harvey, and Soja is a commitment to progressive practices. For Harvey, a socialist reordering of the city is needed to mitigate spatial inequality. For Soja, he seeks to foment a rise of spatial consciousness and his book documents the synergies among labor and community groups, the Los Angeles urban planners, and the geography and planning departments at UCLA.

foregrounding certain features of the built environment – transportation corridors, residential and commercial developments, central business districts, suburbs, etc. – other features are backgrounded. The social impacts of capital on these “grey” infrastructures are apparent, but roads and real estate are embedded in a larger “green” matrix of the urban environment. New strains of critical geography have started to tackle questions of nature in the city.

Urban Political Ecology and Green Gentrification

Political ecology is a wide-ranging research agenda focused on economic, political, and environmental interrelationships. Rather than a field of consistent theoretical or methodological approaches, it is a way to explain human-environment relations with respect to cross-scale chains of explanation, marginalized communities, and political economy (Robbins 2004). Early political ecology work focused on less developed countries, especially in the Global South, where researchers explained local resource use patterns in the context of regional and global capital markets (Blaikie and Brookfield 1987; Bassett 1988). Later work continued this line of inquiry and expanded its study areas to include more developed countries and cities (Desfor and Keil 2004; Swyngedouw 2004; Robbins 2007).

Urban political ecology has emerged recently, providing ways to examine local formations of nature and its “manipulation to suit political, ecological, economic and cultural values” (Pincetl 2007). In an early review article, Keil (2003) traces the multiple and diverse origins of urban political ecology: Marxist urban theory (à la Harvey and Smith), social ecology (à la the Chicago School of sociology), urban ecology (à la the urban Long Term Ecological Research stations), and environmental justice theory and practice (à la Bullard and Agyeman). Research in this field focuses on the political, economic, and cultural factors on the production of urban environments. Loci of topics include the politics of urban water (Bakker 2003, 2005; Swyngededow 2004); ecological modernization (Desfor and Keil 2004); urban energy flows and metabolism (Kaika 2004; Heynen, Kaika, Swyngedouw 2006); the urbanization of nature (Gandy 2003; Pincetl 2007); urban forestry (Heynen, Perkins, and Roy 2006; Perkins 2011) and green infrastructure (Finewood 2016; 2019).

With respect to spatial justice, urban political ecology highlights the ways in which uneven resource distribution, concepts of nature, and the politics of sustainability can amplify urban inequities. For example, contemporary redevelopment projects are now often coupled with “green” initiatives such as walkable neighborhoods, public transport (especially light rail), and neighborhood in-fill (Dale and Newman 2009). Sometimes called the “parks, cafes, and Riverwalk” model of urban sustainability (Curran and Hamilton 2012), these greening projects are often geared toward high-income residents who are being enticed by cities to move downtown. This type of green development drives up real estate prices and displaces low- and middle- income residents through a process called “environmental gentrification” (Checker 2011). Sometimes called ecological gentrification or green gentrification, a number of scholars have used the concept to explore urban issues such as homelessness in public green spaces (Dooling 2009); the language of sustainability and green consumption (Quastel 2009); and regional eco-states and the “sustainability fix” (While, Jonas, and Gibbs 2004, 2010; Goodling, Green, and McClintock 2015). Although theories of environmental gentrification are coming into focus, more research is needed to develop a common framework. In order to better understand its processes and outcomes, more empirical and spatial-analytic studies are needed to quantify its scope and magnitude (Anguelovski et al. 2019).

Chapter Two: Research Setting, Questions, and Methods

Research Setting

The study area for this project is the Denver Metropolitan Area in Colorado, U.S.A. Denver was founded in 1858 along the eastern edge of the Rocky Mountains during the Pikes Peak gold rush. Although it originally grew as a mining, railroad, and agriculture town, it is now a major international economic hub for energy, defense, tourism, and recreation. Denver's current population is estimated to be 727,211 and is one of the fastest-growing U.S. cities, with an estimated 21.2 percent population increase between 2010 and 2019 (U.S. Census Bureau 2020a). The city is part of the larger Denver-Aurora-Lakewood Metropolitan Statistical Area with a 10-county total population of 2,967,239 (Figure 2).

The current population explosion creates significant social and environmental challenges in the areas of affordability, equity, mobility, and sustainability (Goetz and Boschmann 2018). Housing demand is on the rise, leading to higher prices for houses and apartments and displacing lower-income residents through the process of gentrification. The quick rise in population is also taxing to the transportation infrastructure, leading to traffic congestion and massive expenses to fix roads. As new development tries to keep pace with population, housing and infrastructure density is on the rise, with pressure mounting on the natural environment. The area is known for its scenic views of the

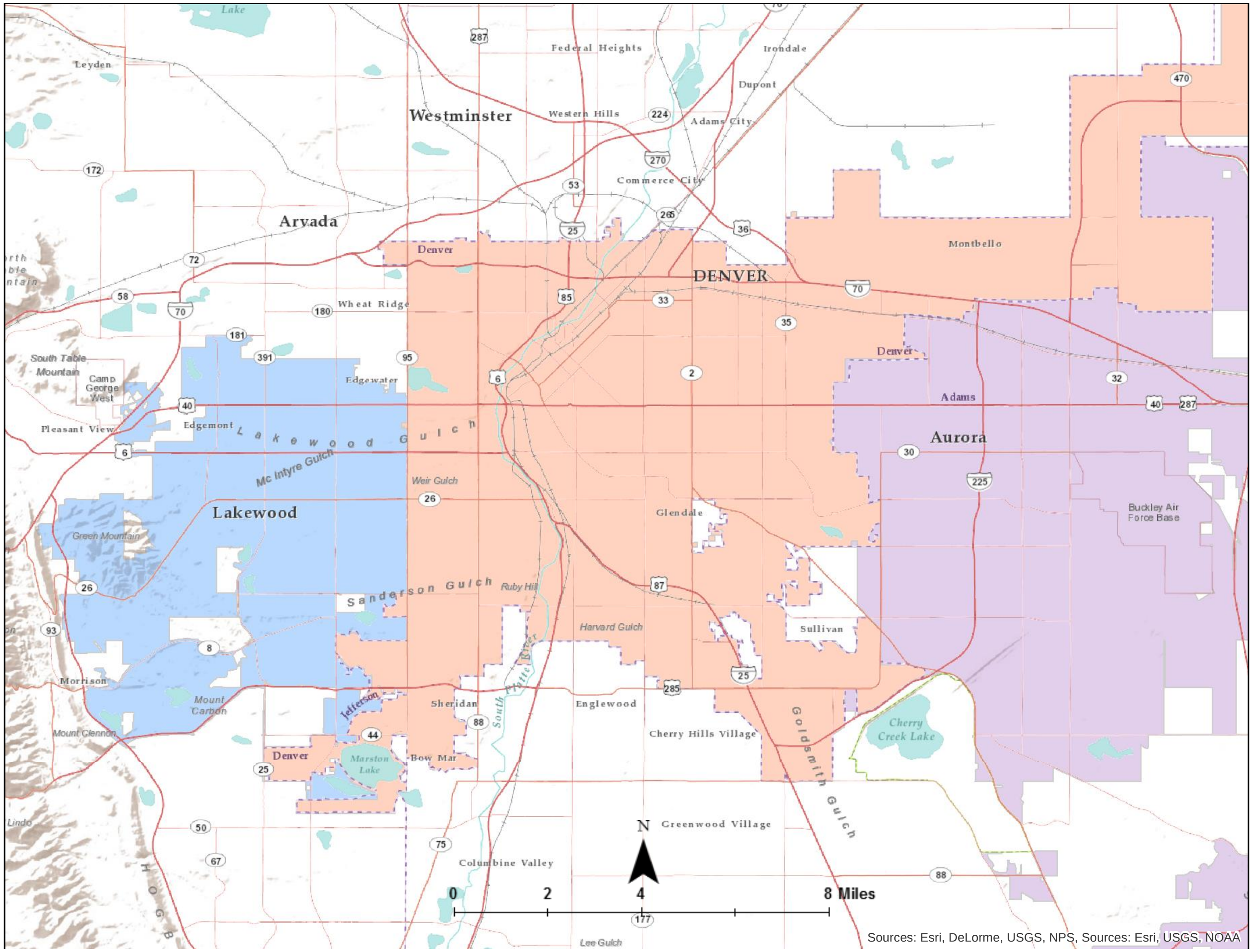


Figure 2 - Map of the Denver-Aurora-Lakewood Metropolitan Statistical Area

Rocky Mountains and numerous open space parks surrounding the metropolitan area. Dating back to the 1960s, the Colorado Front Range has been a national leader in open space conservation, regional planning, and smart growth (Inter-County Regional Planning Commission 1964; Goetz and Boschmann 2018). As Denver attempts to ameliorate current problems with sustainability initiatives such as transit-oriented development, green building ordinances, and climate action plans (City and County of Denver 2020), it is important to assess the social equity and environmental outcomes of these initiatives.

The value of parks and civic beauty influenced the growth of Denver from its inception. Its first open space, Curtis Park, was donated to the city by early land developers in 1868 who realized that houses in their new neighborhood were worth more with a park than without (Goodstein 2003). Other developers followed suit, cutting diagonal roads in their new subdivisions, such as Park Avenue and Bonnie Brae Boulevard, and reserving undeveloped land for greenery. Influenced by the City Beautiful movement, most of the city's large urban parks were created during the late 1890s and early 1900s, boosting its reputation as the "Queen City" in the American West (Leonard and Noel 1990). The parks and green parkways built in the early 20th century became the backbone to one of the best park systems in the U.S. The Trust for Public Land's ParkScore index ranks Denver in the top 30 cities for park access, investment, acreage, and amenities (Trust for Public Lands 2020). However, the city's park acreage, at 8 percent, is far below the national average of 15 percent.

Denver is one of the most culturally diverse cities in the Intermountain West, but also has a history of discrimination. According to 2019 Census estimates, its population is approaching parity between White residents and non-White residents, with White populations at 53.7 %, Hispanic or Latino at 30.3 %, and Black populations at 9.4 %. Median household income and per capita income is higher than the national average. The percentage of residents with bachelor's degrees or higher is 47.9, compared to the national average of 31.5. The owner-occupied housing rate is only 49.6 %, far below the national rate of 63.8 %. The median home value is $357,300 – over $150,000 more than the national average of $204,900 (Table 2).

Table 2 - Select demographic information of Denver, Colorado (2019 estimates). A full table Denver's demographic trends is available in Appendix B

Category	**United States**	**Denver**
Black or African American alone	13.40%	9.40%
American Indian and Alaska Native alone	1.30%	1.00%
Asian alone	5.90%	3.80%
Native Hawaiian and Other Pacific Islander alone	0.20%	0.10%
Two or More Races	2.70%	3.60%
Hispanic or Latino	18.30%	30.30%
White alone, not Hispanic or Latino	60.40%	53.70%
Median household income (2018 dollars)	$60,293	$63,793
Bachelor's degree or higher, persons age 25+	31.50%	47.90%
Per capita income in past 12 months (2018 dollars)	$32,621	$41,196
Owner-occupied housing unit rate	63.80%	49.60%
Median value of owner-occupied housing units	$204,900	$357,300

These data show that despite their higher than average income and education, Denver residents tend to live in rentals and pay more for housing.

Like most U.S. cities, a history of discrimination and segregation has left its mark on Denver’s built environment. Residential maps created by the U.S. government’s Home Owner’s Loan Corporation, also known as “redlining” maps provide a look into the history of discrimination in Denver. The loan corporation’s staff, along with local lenders, real estate agents, and developers graded neighborhoods on a scale of A, B, C, or D to reflect their “mortgage security”, which were visualized in color-coded maps (Figure 3). Neighborhoods receiving the highest grade of "A”, colored green on the maps, were deemed minimal risks for banks and other mortgage lenders when they were determining who should receive loans and which areas in the city were safe investments. Those receiving the lowest grade of "D", colored red, were deemed "hazardous" (Nelson et al. 2020).

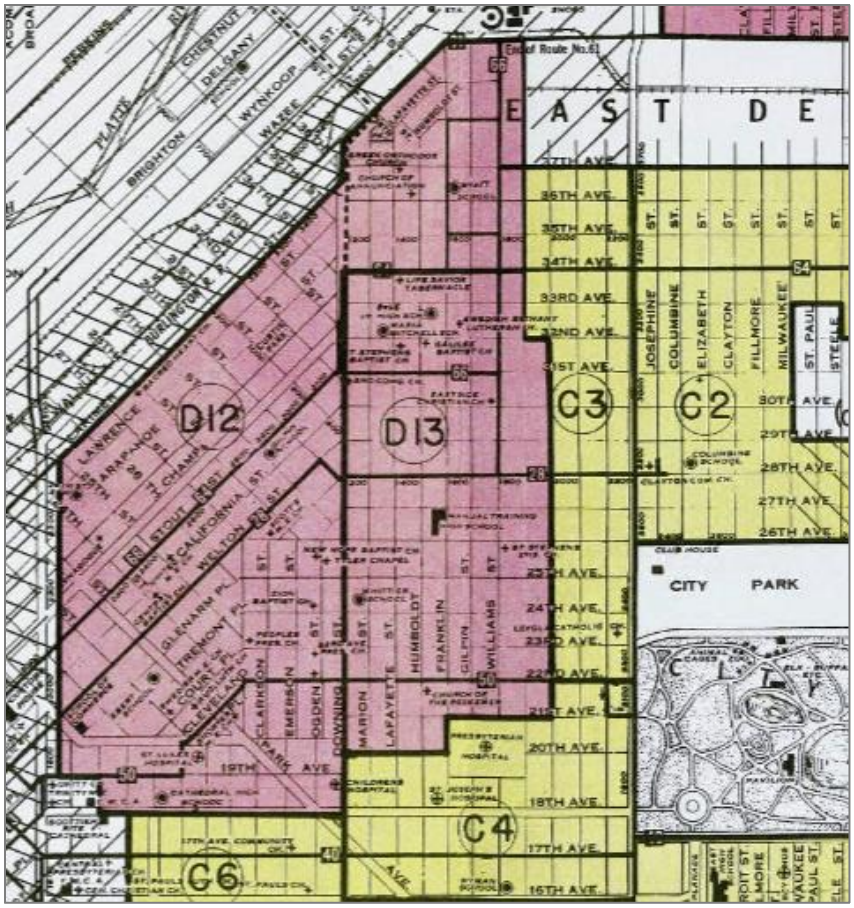


Figure 3 - Redlining map of Denver, showing the "Grade D" African American neighborhood of Five Points

Accompanying written assessments documented neighborhood attributes and its racial and income makeup. For instance, assessors described the “favorable influences” of African American neighborhood Five Points (D12), as having adequate transportation, utilities, and schools. It’s “detrimental influences” were “negro and foreign infiltration”. This overt racialization of home ownership effectively kept African Americans and immigrants segregated into neighborhoods until the late 1960s when the Fair Housing Act was enacted.

Research Goals and Questions

This dissertation examines the inequalities of urban green space in the Denver Metropolitan Area. In order to provide insight into its spatial patterns and underlying human geography, the primary goals of this research are to:

- quantify urban green space access and their associated ecosystem services;
- explore statistical relationships between urban green space and demographic trends in order to assess if there are any disparities;
- and explain inequities through the lenses of environmental justice and critical geography in order to better understand its social context.

This research is guided by the overarching research question: does urban green space mitigate or multiply social inequality? To that end, specific research questions are posed below.

Are urban green spaces and their ecosystem services evenly distributed spatially across the Denver Metropolitan Area? Urban green spaces are not expected to be equally distributed, due to the underlying structure and morphology of the urban environment. I expect there to be major differences among the three municipalities.

If there are disparities, how are they positively or negatively correlated with income, housing prices, and minority populations? Lower income and residents of color are expected to have less access to urban green space overall. However, I'm expecting to see major differences between general green space and their ecosystem services, with affluent neighborhoods having access to very good quality green spaces.

What are the reasons and ramifications of this disparity? Disparities are likely due to historical and current economic and racial conditions. These disparities are likely amplifying urban inequality.

Methods

The goals and questions of this dissertation are addressed using quantitative and qualitative approaches. Combining Geographic Information Systems, equity mapping techniques, spatial and statistical analysis, fieldwork, document analysis, and historical research allows for complex socio-environmental issues to be examined from multiple angles. The specific methodology used for each study is described in the appropriate chapter, since each chapter uses slightly different methods.

Chapter Three: Environmental Injustice? Green Space Access in the Denver Metropolitan Area

Introduction

Numerous benefits are provided by urban green space. Urban parks and open space provide recreational opportunities for residents, linked directly to health, well-being, and aesthetic benefits (Bolund and Hunhammer 1999). Green infrastructure – riparian corridors, urban forests, and storm water catchment systems – supports biodiversity, regulates air temperatures, and protects drinking water (Tzoulas et al. 2007). Community gardens and urban farms foster cultural ties and food security (Baker 2004; Corrigan 2011). Urban green space types fall on a “green-to-grey” continuum, and includes green belts, open space, forest reserves, wetlands, storm water ponds, green roofs, bioswales, city parks, community gardens, tree rows, and vacant lots.

Recent studies suggest that one form of green space, urban parks, are not always provisioned evenly in cities (Wolch, Wilson and Fehrenbach 2005; Byrne and Wolch 2009). Access is often stratified along socio-demographic lines such as income, race, age, and gender (Boone et al. 2009). People of color are especially likely to live in park-poor neighborhoods, unable to benefit from the amenities they provide – blocked from what David Harvey (2012) calls their “right to the city”. Park access has emerged as a compelling environmental justice concern (Wolch, Byrne, and Newll 2014; Grove et al. 2018), yet most research in the U.S. has been confined geographically to mature and discrete coastal cities. More studies are needed that assess the totality of urban green space disparities across municipal boundaries, especially in high growth regions.

Environmental Justice and Urban Park Research

The environmental justice movement in the U.S. has evolved over the decades from primarily documenting minority community's disproportionate proximity and exposure to environmental hazards to the unequal distributions of amenities in urban areas. Starting in the 1980s, environmental justice activists, academics, and policy makers began to recognize that low income and minority populations were being exposed disproportionately to environmental hazards. In 1982, one of the first national protests of hazardous waste was triggered in Warren County, North Carolina, one of the poorest counties in the state (Bullard 1990). The state government wanted to create a burial site for PCBs in the town of Afton, which was 84 % African American, but the dump trucks were met with demonstrations and protests. Although they were ultimately not able to stop the toxic landfill from being built, the protests drew national media attention and these efforts were the first major milestone in the national movement for environmental justice.

In the 1990s, environmental justice leaders were successful in gaining the attention of the Bush and Clinton administrations. In 1992, the Bush Sr. administration established the Environmental Equity Working Group in the EPA and initiated federal meetings on environmental justice issues with community leaders. In 1994, President Clinton issued Executive Order 12898: Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. The order directed federal government to make environmental justice concerns part of federal decision-making processes (DOE 2020). Since the early 1990s, national environmental justice strategies and policies have been housed in the Environmental Protection Agency. As environmental justice struggles gained national recognition, a strain of recent environmental justice research and practice has broadened its scope from a singular focus on environmental burdens to include the distribution of goods and amenities (Boone et al. 2009). An early legal precedent for this type of analysis comes from a 1971 ruling of the U.S. Fifth Circuit court. The appellants in the case were Black citizens of Shaw, Mississippi who alleged that the town provided municipal services such as street lighting and paved roads in a discriminatory manner (U.S. Court of Appeals 1971). It was a landmark ruling because it established the legal precedent that if a community elects to provide a public service, it must be made equally accessible to all citizens (Marcuse 1978; Sister et al. 2010).

According to Sister et al. (2010), disparities in the distribution of public resources are ultimately environmental justice struggles, and "differential access to urban public facilities that privileges one group and disadvantages another may also constitute environmental injustice." To date, research on the allocation of urban amenities in the context of environmental justice have focused on vegetation cover (Pedlowski et al. 2002; Heynen, Perkins, and Roy 2006; Landry and Chakroborty 2009; Schwarz et al. 2015) and the placement of parks (Low, Taplin, and Scheld 2005; Wolch, Wilson, and Fehrenbach 2005; Boone et al. 2009; Rigolon 2016). Due to the spatial nature of these emerging environmental justice concerns, geographers have been at the forefront of this research agenda. Boone et al. (2009) offer several perspectives on environmental justice and urban parks, such as the political and historical factors that influence park distribution, park neglect and safety, and the racial politics of park development. Through historical research, they found that segregation ordinances and policies of the Baltimore Parks and Recreation Board may have led to park congestion in African American neighborhoods. While summarizing then current literature on environmental justice and public parks, Byrne and Wolch (2009) used cultural landscape and political ecology theory to draw attention to the historical, social, and political-economic process that create “park spaces”. Tracing the evolution of parks in Europe and the U.S. – from the City Beautiful Movement onward – they talk about parks as “spaces of exclusion”, and how park use varies widely by race. One of their arguments was that racial groups exhibit very distinct preferences for why they visit, and what they do, at parks. African Americans tend to enjoy more sociable, formal, sports-oriented activities; whereas Whites are said to focus more on individualistic pursuits such as jogging and prefer secluded settings (Gobster 2002; Byrne 2012).

Park accessibility and supply have been shown to be key constraints on park use across urban communities. In general, studies suggest an uneven distribution of environmental amenities that favor White populations and affluent communities. Accordingly, people of color are likely to live in vegetation and park poor neighborhoods (Boone et al. 2009; Byrne and Wolch 2009). As Wolch, Byrne, and Newell (2014) point out, lower income and non-White communities experience lower levels of park service compared to White populations and higher income communities (Wolch et al. 2005;

Abercrombie 2008; Sister et al. 2010;). However, there tends to be less straightforward relationships between park access and race or socioeconomic status, with roles reversed under certain situations (Boone et al. 2009; Sister et al. 2010). Additionally, park visitation is dependent on other factors besides park location, such as amenities, overcrowding, and cultural preference (Brownlow 2006; Gobster 2002; Sister et al 2010). One possible reason for these contradictory conclusions are the methods that researchers use to measure park access. Geographic scale, spatial analyses, metrics, and models differ greatly from study to study.

Park Access Research

Despite the growing literature on environmental justice and parks, there is no consensus among researchers about how to measure park access. Rigolon (2016) reviewed the methods and conclusions of 49 articles from peer-reviewed journals which focused on parks, green space, equity, equality, and environmental justice. A key finding was that there have been three types of commonly used park access parameters: park proximity, park acreage, park quality. Park proximity refers to the distance between homes and the closest park. Proximity has been the most used parameter, yet the literature revealed inconclusive findings for it with respect to socio-economic indicators. Many of these studies showed that Black and Latino populations live closer to parks than White populations in such places as Baltimore (Boone et al. 2009) and Los Angeles (Wolch, Wilson, and Fehrenbach 2005), since older cities have downtown neighborhoods with many small parks. Park acreage and park quality, on the other hand, showed striking inequalities. Among the articles reviewed, half of them showed that lower-income and minority groups had access to far less park space than higher-income and White groups in cities as varied as Tulsa (Talen and Anselin 1998) and Berlin (Kabische and Haase 2014). According to many articles, the quality of parks (affected by amenities, aesthetics, maintenance, and safety) were relatively low in lower income and minority neighborhoods than in other neighborhoods, e.g. in Australia (Leslie et al. 2010) and Denver (Rigolon and Flohr 2014). According to this review, park proximity may not be the best parameter to use when trying to identify spatial inequality. It is clear, however, that injustices existed for low income and people of color with regards to park acreage and park quality – and it appears to be consistent across scales.

Taken together, these findings document environmental injustices associated with access to urban parks, which should warrant more study and interventions (Wolch, Byrne, and Newell 2014). Just as traditional environmental justice studies have typically focused on a single case study, so too has most park access research. Few comparative analyses using the same methodology have been done (Rigolon 2017). Yet this method could reveal consistent and significant patterns across cities of different size, morphology, and age class. A metropolitan area consisting of multiple adjacent municipalities offers an ideal scale at which to study park access.

Methods

Study Area

The Denver-Aurora-Lakewood Metropolitan Statistical Area (MSA) is a ten-county region in north central Colorado situated along the eastern edge of the Rocky Mountains. It is a unique yet emblematic site to study green space inequality due to its rapid population growth, environmental history, residents' active lifestyle, and racially diverse population. The Denver MSA is one of the fastest growing regions in the U.S., with a total population of 2,967,239 – up 16.7 percent from 2010. The MSA average rate of growth for the same period was 7.5 percent (U.S. Census Bureau 2020b). The current population explosion creates significant social and environmental challenges in the areas of affordability, equity, mobility, and sustainability (Goetz and Boschmann 2018). As new development tries to keep pace with population, housing and infrastructure density is on the rise, with pressure mounting on the natural environment.

The area is known for its scenic views of the Rocky Mountains and numerous open space parks surrounding the metropolitan area. The value of parks and civic beauty influenced the growth of Denver from its inception. Its first open space, Curtis Park, was donated to the city by early land developers in 1868 who realized that houses in their new neighborhood were worth more with a park than without (Goodstein 2003). The parks and greenways built in the early 20th century became the backbone to one of the best park systems in the U.S. Dating back to the 1970s, with the rise of environmentalism, the Colorado Front Range has been a national leader in regional planning and smart growth, which led to large tracts of conserved greenbelts and open space. The Trust for Public Land's ParkScore index ranks Aurora and Denver in the top 30 cities for park access, investment, acreage, and amenities (Trust for Public Lands 2020).

The Denver-Aurora-Lakewood MSA is one of the most culturally diverse in the Intermountain West. The three largest municipalities in the MSA – Denver, Aurora, and Lakewood – were selected for this study. According to 2019 Census estimates, Lakewood is the least racially diverse, with Whites making up 69.4 % of the population; Denver is approaching racial parity between White and non-White residents, with White populations at 53.7 %, Hispanic or Latino at 30.3 %, and Black populations at 9.4 %. Aurora is the most diverse, with Whites being in the minority at 45 %, Hispanic at 28.4 %, Black at 16 %, and Asian at 6.3 %. Aurora is a national hot spot for immigration, with nearly 20% of its population foreign born and twice as many people identifying as 2 or more races than the national average (Appendix 1). Median household income and per capita income is higher than the national average for all three cities, except for Aurora which lags in per capita income. Other social and demographic information that stands out: the percentage of Denver residents with bachelor's degrees or higher is 47.9, compared to the national average of 31.5; the owner-occupied housing rate for all three cities is below the national rate of 63.8 %; and the median home value is significantly higher than the national average of $204,900, with Denver's median home value at $357,300. Like many cities in the U.S. Denver's Black and Latino populations have experienced discrimination in housing and education, which are inscribed in the city's history through redlining and fights over busing (Goetz and Boschmann 2018)

Geospatial and Statistical Analyses

Data collection and processing

Using Geographic Information Systems, I studied how access to parks varied at the census block group level by race/ethnicity, income, and land use characteristics. I collected open access GIS data from the Denver Regional Council of Governments (DRCOG), including county and municipal boundaries, and their "Open Space" dataset from their Regional Data Catalog (DRCOG 2020). Census block group and American Community Survey data were collected from the U.S. Census Bureau. Various environmental data were collected for reference (Table 3).

Table 3 - Data used in the study

Dataset	Source	Year	Notes
Regional Open Space	DRCOG*	2017	Includes private, local, municipal, state, and federal parks and green space
County Boundaries	DRCOG	2019	U.S. census TIGER data
Municipality Boundaries	DRCOG	2019	U.S. census TIGER data
Roads	DRCOG	2016	U.S. census TIGER data
Census Block Groups	U.S. Census Bureau	2016	
American Community Survey 2012-2016	U.S. Census Bureau	2016	More recent ACS data was not available at the time
National Land Cover Dataset – Impervious Surface and Tree Canopy	Multi-Resolution Land Characteristics (MRLC) consortium	2016	Only used for reference. At 100 m resolution, it was too coarse for this study

*Denver Regional Council of Governments

Preprocessing and geoprocessing were performed in ArcGIS 10.5. It consisted of creating a geodatabase; importing datasets; re-projecting all datasets to NAD 1983 UTM Zone 13 North coordinate system (Transverse Mercator projection); querying out counties outside of the study area; clipping municipalities to the counties; and clipping green space polygons to the municipalities, which led to the isolation of the three selected cities and their 995 green spaces (Figure 4). Slivers and other geometric errors were cleaned and resolved from the census block group dataset.

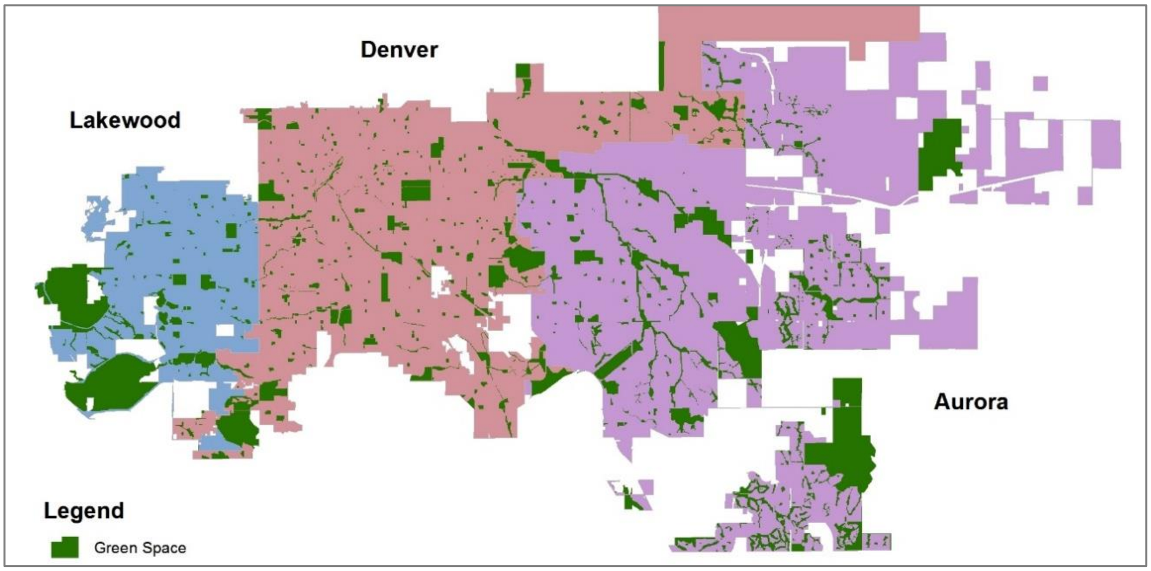


Figure 4 - The Denver-Aurora-Lakewood study area with gren spaces

In order to focus on non-excludable and non-rival public spaces, I omitted golf courses, cemeteries, water parks, private parks, and recreation centers. Street medians and reservoirs were also excluded, as were all federal and state parks (Table 4).

The unit of analysis for this study was the census block group, which provides an excellent scale to examine neighborhood characteristics and green space access. I excluded census block groups within the Denver International Airport area due to very low population and absence of green spaces.

Table 4 - Green space units and managment regimes

Green Space Unit	Primary ES	Spatial Scale	Management Regime
Parks	Cultural	Neighborhood	Municipal
Community garden	Provisioning	Neighborhood	Municipal
Public Schoolyards and playgrounds; University grounds	Cultural	Neighborhood	Municipal, State, Private
Green infrastructure (constructed wetlands, riparian buffers, urban tree canopy)	Regulating	Neighborhood	Municipal, County
Cemeteries	Cultural	Neighborhood	Private
Golf course	Cultural	Neighborhood	Municipal, Private
Lake	Regulating	Neighborhood Regional	State
Open space parks	Regulating/Cultural	Regional	County, Denver Regional Council of Governments, Private
State Park	Regulating/Cultural	Regional	State
Regional trail system	Cultural	Regional	County, DRCOG
Wildlife Refuge	Regulating	Regional	Federal
National Forest	Regulating/Provisioning	Regional	Federal
Rivers	Regulating	Regional Continental	State, Federal

Green space data

Green space access was calculated by using 1) the number of green spaces per 1,000 residents of a census block group (a simple measure of proximity) and 2) the percent green space area within a census block group (a simple measure of acreage). For the acreage measure, I added a half mile buffer around each green space and calculated the total acreage within the buffer. Many U.S. studies have used this half mile distance to calculate acreage, as it roughly equates to a ten-minute walk (Wolch, Wilson, Fehrenbach 2005; and Boone et al. 2009; Harnik and Martin 2016; Rigolon 2017).

Statistical analysis

Bivariate correlation analysis between social and environmental variables has been a common tool in environmental justice research (Schwarz et al. 2015). It advances equity mapping techniques (Talen 1997 and 1998; Wolch, Wilson, and Fehrenbach 2005; Rigolon 2017) with statistical inferences that help establish statistically significant baseline disparities in the allocation of environmental amenities and hazards. For this study, bivariate Spearman's correlation was used as a simple aspatial indicator of association between the green space access variables on the one hand and social and land use variables on the other (e.g. high values in one dataset match high values in the other). Non-parametric analysis was used due to non-normal distribution of most variables. Social variables included indicators of race, ethnicity, age, educational attainment, income. For race and ethnicity variables, I used percent White, Hispanic, Black, Native American, and Asian. For educational attainment I used "percent no high school diploma" and "percent with a bachelor's degree or higher". For income, I used per capita income and median household income. Since green spaces are embedded in the urban landscape, the following land use variables were also used: median year built, population density, and distance from central business district (CBD). All correlation analyses were performed in SPSS Version 17.0.

Results

Correlation analyses show a complex pattern of environmental spatial inequalities, as well as equalities. Positive scores indicate positive relationships and negative scores indicate negative relationships. Although the R scores were all somewhat low, these are still fairly significant results, especially for environmental justice studies like this that combine social and environmental variables (Schwarz et al. 2015).

Table 5 - Green space correlation results for Lakewood

	Percent Greenspace		Greenspaces per 1000	
Variable	**R**	**Sig**	**R**	**Sig**
Proportion White	0.140		0.144	
Proportion Hispanic	-0.245	**	-0.333	**
Proportion Black	0.072		-0.008	
Proportion Native American	-0.004		-0.037	
Proportion Asian	0.090		-0.027	
Median Resident Age	0.076		0.155	
Proportion No HS	-0.263	**	-0.243	**
Proportion Bachelors +	0.290	**	0.163	
Per Capita Income	0.263	**	0.126	
Median Household Income	0.162		0.053	
Median Home Value	0.033		0.015	
Median Year Built	0.347	**	0.034	
Population Density	0.048		-0.493	**
Dist from CBD	0.312	**	0.097	
n (census block groups)	137		137	

0.6	0.5	0.4	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

For *Lakewood*, Hispanic and relatively low-education populations have relatively little access to green space for both acreage and proximity (Table 5). More educated and higher income populations have better access. As for land use variables, median year built and distance form central business district is positively correlated with green space access; whereas population density is negatively correlated with green space.

For *Denver*, minority and lower income populations have slightly better access to green space than White and higher income populations. Since correlation coefficients were mostly insignificant with green space proximity (green space per 1,000 residents), I decided to show results for the unnormalized raw numbers of green spaces per census block (far-right column Table 6). Adding these correlations helps draw out information, showing that White populations not only have poor access to green space acreage, but the number of green spaces as well. As age, education, and income go up, their overall access to green space goes down. Mirroring Lakewood, the most statistically significant finding is the negative correlation between greenspace per 1000 residents and population density.

Table 6 - Green space correlation results for Denver

	Percent Greenspace		**Greenspaces per 1000**		**Number of Greenspaces**	
Variable	**R**	**Sig**	**R**	**Sig**	**R**	**Sig**
Proportion White	-0.162	**	0.012		-0.209	**
Proportion Hispanic	0.125	**	0.004		0.179	**
Proportion Black	0.079		-0.114	*	0.116	**
Proportion Native American	-0.011		0.009		0.067	
Proportion Asian	0.085		-0.110	*	0.061	
Median Resident Age	-0.055		0.090	*	-0.196	
Proportion No HS	0.095	*	0.061		0.171	**
Proportion Bachelors +	-0.154	**	0.019		-0.180	**
Per Capita Income	-0.162	**	0.026		-0.166	**
Median Household Income	-0.026		-0.012		-0.095	*
Median Home Value	-0.166	**	0.029		-0.104	*
Median Year Built	0.265	**	0.003		0.315	**
Population Density	-0.020		-0.333	**	-0.124	**
Dist from CBD	0.150	**	-0.180	**	-0.018	
n (census block groups)	479		479		479	

0.6	0.5	0.4	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6

*Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level.

For *Aurora*, all non-White and lower income populations have less access to green space than White, more affluent, and more educated residents. Population density and distance from central business district appear to be major factors on access to green space. For each variable, the correlation scores were higher for proximity (greenspaces per 1000) than acreage (percent greenspace).

Table 7 - Green space correlation results for Aurora

	Percent Greenspace		**Greenspaces per 1000**	
Variable	**R**	**Sig**	**R**	**Sig**
Proportion White	0.201	**	0.326	**
Proportion Hispanic	-0.164	**	-0.240	**
Proportion Black	-0.089		-0.213	**
Proportion Native American	-0.059		-0.086	
Proportion Asian	-0.057		-0.122	
Median Resident Age	0.026		0.167	**
Proportion No HS	-0.216	**	-0.284	**
Proportion Bachelors +	0.131	*	0.208	**
Per Capita Income	0.180	**	0.288	**
Median Household Income	0.150	*	0.208	**
Median Home Value	0.107		0.154	*
Median Year Built	0.214	**	0.262	**
Population Density	-0.240	**	-0.587	**
Dist from CBD	0.315	**	0.361	**
n (census block groups)	246		246	

0.6	0.5	0.4	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6

*Correlation is significant at the 0.05 level.
**Correlation is significant at the 0.01 level.

Discussion

Results suggest that environmental injustice in the form of spatial inequities do exist in the Denver Metro Area, but it applies differently to each city. Race and income are major factors in how many and how much green space residents can easily access. Although not usually included in environmental justice studies, land use characteristics such as population density and distance from CBD appear to be important predictors as well. This is born out in other studies which found that neighborhood age and population density are strong predictors of urban vegetation (Boone et al. 2010).

The most statistically important environmental justice disparity seen for Lakewood is that Hispanic populations have poor access to green spaces. Lakewood was incorporated in 1969 and grew out of urban expansion from Denver's central core. As seen below (Figure 5), most Hispanic and lower income neighborhoods are in the eastern section, which is relatively close to downtown Denver. White and higher income neighborhoods are in the west, which may reflect ongoing "white flight"-type settlement patterns or White communities' preference for green space that provides secluded activities (Gobster 2002) and conservation (Payne, Mowen, and Orsega-Smith 2002).

Among the three study sites, Lakewood has the highest percentage of green space, at 23 %. Population density and median year built appear to be statistically significant indicators, likely due to the sparser neighborhoods of people who live in new homes hemmed in by the Jefferson County open space system of greenbelts. This leads me to believe that the size and configuration of Lakewood's green spaces are tied to its early urban expansion. Much of that growth occurred during the post-war housing boom. As ranches subdivided, and rural foothill developments increased, regional planning entities earmarked numerous Lakewood open spaces for park development (Inter-County Regional Planning Commission 1963).

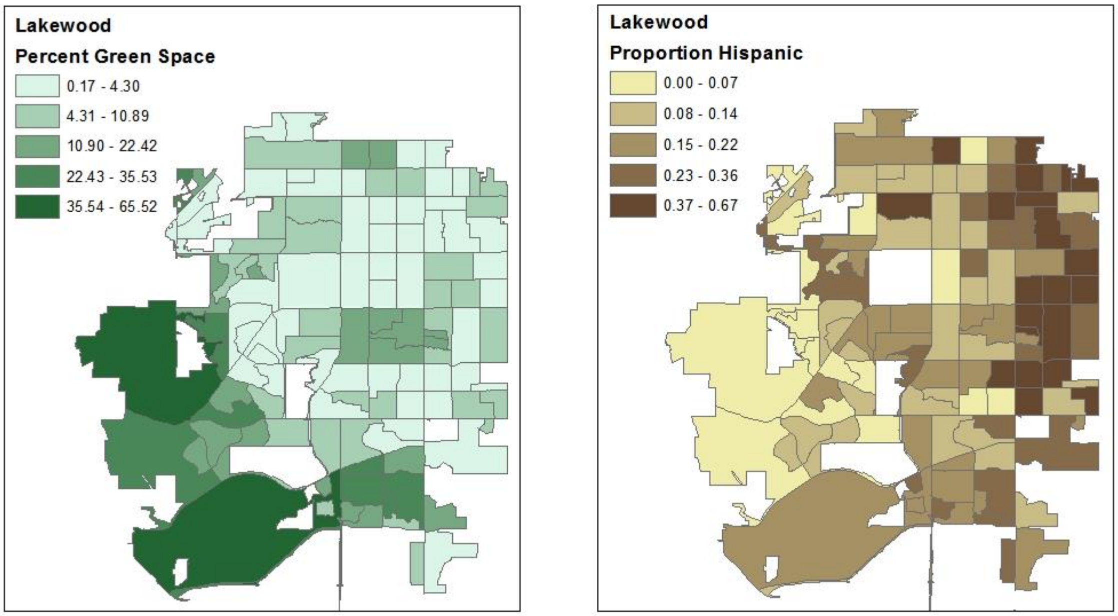


Figure 5 - Percent green space and proportion Hispanic maps for Lakewood

There appear to be no statistically significant environmental justice disparities in Denver. In fact, the most striking result is that White populations have less access to green space than their Hispanic and Black counterparts. This reflects trends in other cities such as Baltimore (Boone et al. 2009; Grove et al. 2018) where White populations tend to live in affluent neighborhoods with large parks and Black populations often live in older downtown neighborhoods with numerous small parks. However, as younger and whiter populations are moving to downtown Denver (Goetz and Boschmann 2018), there may be reason for concern that these mixed results might be signals of gentrification, although more research is needed to confirm this dynamic. Another possible reason for parity among racial groups is that roughly 20 % of Denver's green spaces are elementary schools, which are disbursed throughout Denver's many neighborhoods. Denver considers these "Functional" parks, whereas most other green spaces are listed as

“Amenity” parks. Denver’s Learning Landscapes program, which has over the last two decades, refurbished most of Denver’s elementary schoolyards into “safe multi-use parks tailored to the needs and desires of their neighbors and communities” (Learning Landscapes 2020). Denver counts the entire school property, not just the playground and ballfields, as green space. Additionally, Denver’s green spaces appear to be a mix of pleasure ground, recreation, and pocket parks – a common configuration of cities that were founded in the late 19th century (Cranz 1982).

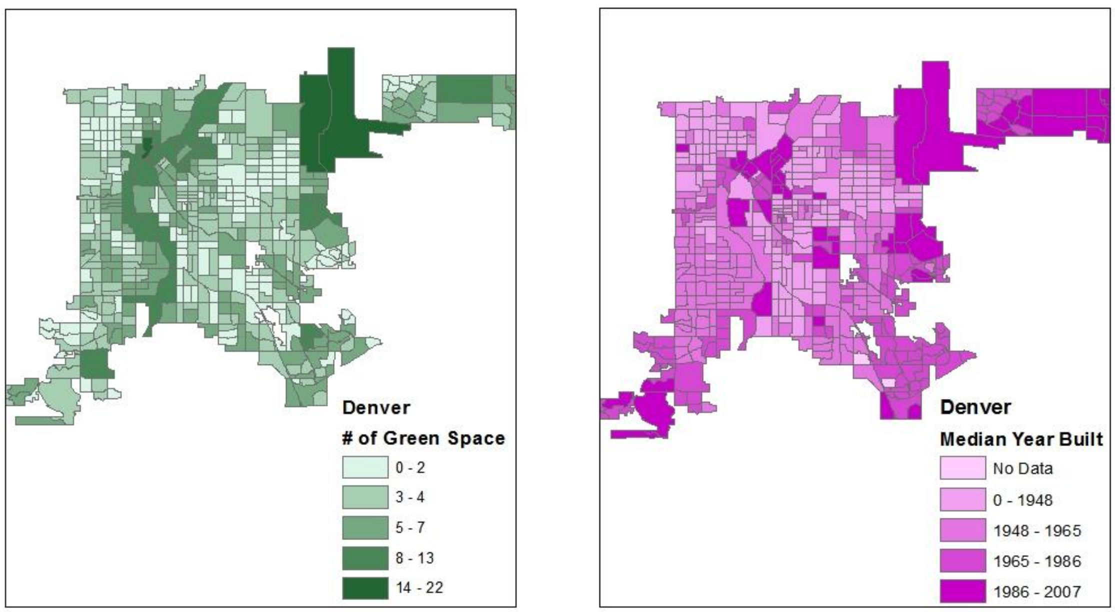


Figure 6 - Percent of green space and median year built maps of Denver

As Figure 6 shows, neighborhoods with more greenspaces are mainly along an s-shaped north-south corridor, and in the northeast side of Denver. A major interstate runs the north-south corridor, and it also home to the region’s warehouses. The surrounding neighborhoods are comprised of large census blocks, which leads to their high numbers of green spaces; and lower home values. It seems paradoxical that green spaces would proliferate in this corridor. However, it is the location of a major environmental amenity – the Platte river – which provides numerous parks and biking paths. Although the number of green spaces is relatively high, this does not mean that they are of high quality or safe, as other Denver green space studies have pointed out (Rigolon 2017). According to the map, another major source of green space is the northeast side. This area was the site of a major international airport that was torn down in the mid-1990s. It has since undergone redevelopment, and its new neighborhoods Stapleton and Lowry were built following new urbanist principles which highlight green space and walkability.

Reviewing the correlation results, Aurora's whiter, older, more educated, and higher income populations that live in less dense neighborhoods far from Denver have better access to green space. Indeed, the most statistically important disparity for this highly suburban majority-minority city is that its White population has much better access to green space than its Hispanic, Black, and Asian populations. As shown in Figure 7, Hispanic neighborhoods are clustered in the northwest corner where there are few green spaces. Many Asian, refugee, and immigrant communities are also located in this section of the city, with the same green space disparities. Interesting questions emerge regarding this. Was it always multicultural? How does this influence the siting, quantity, and quality of new parks?

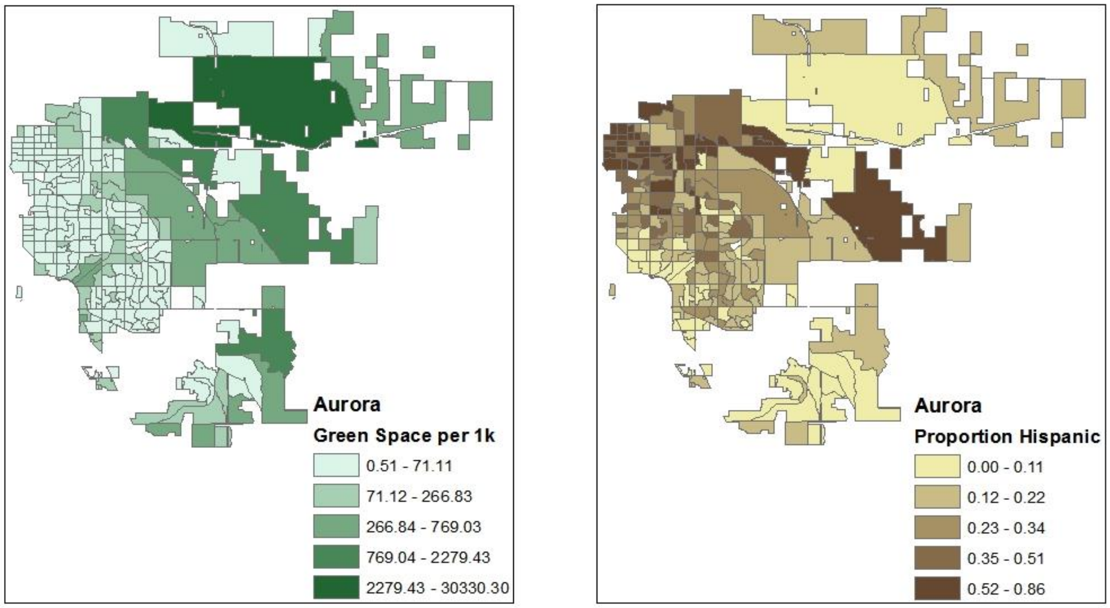


Figure 7 - Green space per 1,000 and proportion Hispanic maps of Aurora

A pattern emerges when looking at the differences between green space measures of access. For each variable, the correlation scores were consistently higher for proximity (greenspaces per 1000) than acreage (percent greenspace). This means that minority populations do not have very good access to large parks, and they especially don't have access to many parks. As with the other two study areas, population density and distance from central business district appear to be major factors on access to green space. Like many suburban areas, Aurora has no discrete center and has the lowest density of the three study sites.

These findings have significant implications for spatial equality across the Denver Metropolitan Area. The inaccessibility of green spaces in lower income and especially Hispanic neighborhoods in Lakewood and Aurora is a major finding of this study. Proximity to green space is surely important, especially for children who lack transportation, but the disparities in park acreage are perhaps more concerning. Having access to large parks with natural features and organized sports programs has been shown to improve park attendance and foster more robust physical activity than small parks (Roemmich et al. 2006; Loukaitou-Sideris and Sideris 2009).

This study shows that lower income, less educated, and non-White populations are not profiting from the economic and environmental benefits associated with green space. Residential property values are significantly higher in neighborhoods with more green space (Conway et al. 2010). Although caution should be used with this line of inquiry due to the real possibility of gentrification (Wolch, Byrne, and Newell 2014), especially in Denver. As for the local environmental benefits of green space, these results suggest that lower income populations may be suffering disproportionately from “urban heat island” effects, where temperatures are warmer in urban areas with no vegetation (Jenerette et al. 2011). A recent study of 108 U.S. cities showed that 94% of neighborhoods with a history of redlining displayed consistent patterns of elevated land surface temperatures by as much as 7 degrees Celsius (Hoffman, Shandas, and Pendleton 2020).

Assessing green space access provides a baseline for understanding current spatial inequalities across the three study areas. Identifying these gaps at the census block group level can help focus planning and policy efforts to neighborhoods which have the greatest disparities (Rigolon 2016). This could be especially true for Lakewood and Aurora, which appears to be lagging Denver in allocating green space equitably. One reason for this may be due to Denver’s Parks and Recreation department which has focused on community engagement and equity in recent years (Denver Parks and Recreation 2019).

The information can also be useful to regional planning organizations like the Denver Regional Council of Governments, which has been touting the importance of open space in the Denver region since the early 1960s (Inter-County Regional Planning Commission 1964). The information provided here may also be useful to local social equity non-profits and environmental groups, such as the Metro Denver Nature Alliance, a coalition of public and private entities who promote equitable access to nature and healthy communities (mDNA 2020).

This study has several constraints that could be addressed in follow-up research. One limitation is that it focused on only two measures of access: proximity and acreage. It does not address the quality of green space. By adding this third element, we may see the dynamics of disparity change drastically. There are many census block groups which may appear to have copious green space, but if they are of low quality, they may suffer from non-use (Byrne 2012; Van Dillen et al. 2012). The main limitation of this study is that it does not fully uncover the reasons why spatial inequalities exist in the study area. For instance, there are many factors why residents choose to live in neighborhoods with or without green space. From an environmental justice standpoint, this study spells out the distributive justice concerns of green space disparities but does not address its procedural or recognition concerns. It would be important to know which factors have the most influence: racial marginality, economic barriers, or simply cultural preference (West 1989). To that end, more research is needed that examines the history of redlining and its impact on green space access. Follow-up studies are needed to determine if current spatial disparities are the product of any formalized exclusionary practices such as segregation or biases in green space acquisition. Finally, in order to tease out why some cities appear to perform better than others with green space parity, a comparative analysis of governance regimes would be needed.

Conclusion

This study was motivated by the perceived growing disparity between green space access and disadvantaged populations. Through spatial and correlation analysis, I established the likely existence of numerous disparities. Lakewood's Hispanic and less educated populations have significantly poor access to green space for both acreage and proximity. The green space parity achieved in Denver appears to act as a mitigator of race and income inequality, although more research is needed in order to gauge the impact that urban growth patterns and gentrification may be having on this outcome. Aurora's White populations have much better access to green space than its Hispanic, Black, and Asian populations. I originally hypothesized the opposite based on neighborhood observations and was surprised to learn that despite Aurora's large non-White population, they tend to cluster in smaller census blocks closer to downtown Denver with relatively small green spaces.

There are clear patterns of social and environmental inequalities etched on the urban green space landscape of Lakewood, Denver, and Aurora. Such disparities warrant more efforts by community activists, local planning departments, and regional entities to improve green space access in underserved neighborhoods.

Chapter Four: Tragedy of the Green Space Commons: Ecosystem Services and Equity in the Denver Metropolitan Area

Introduction

Questions of spatial distribution are generally the purview of geography, but other fields of study also recognize the importance of resource distribution – notably, the field of ecological economics. Ecological economics is a field of study that treats economic capital as a subset of the planet's natural capital. There are three pillars of ecological economics that are recognized as critical to managing economic systems within the planet's life-supporting system: 1) ecologically sustainable scale of human activities; 2) fair distribution of resources and property rights – among the current generation and between generations; and 3) efficient allocation of market and nonmarket resources (Daly 1992; Costanza and Folke 1997).

As one of the three pillars, fair distribution sits alongside sustainable scale and efficient allocation. Although usually thought of in terms of wealth and income, the logic of fair distribution can be applied to other social circumstances, including natural resources and nonmarket goods and services, such as those provided free of charge from the environment. Public goods like common pool resources can be vulnerable to depletion and underappreciation (Hardin 1968). Because they tend to fall outside the market, they are difficult to value (Costanza and Liu 2014). In this regard, public goods and services exhibit a double problem: they are oftentimes undervalued as well as unevenly distributed. Because of this, it's important to characterize and assess how these goods and services are provisioned. Numerous studies have shown that public space such as urban parks are often distributed unevenly across space (Byrne and Wolch 2009). What's uncertain is if the ecosystem services they provide follow this same logic. If so, this may pose serious problems for cities that are working towards sustainability goals and gives food for thought on how the challenges and opportunities for using an ecosystem services framework could lead to better green space allocation.

Urban ecosystem services and green space equity

Ecosystem services are the benefits that people derive from the natural environment (Costanza et al.1997; Daily 1997) or as direct and indirect contributions from ecosystems to human well-being (Kumar 2010). These include *provisioning* services such as food, fresh water, timber, and medicinal plants; *regulating* services such as climate and air quality regulation, water purification, and flood, drought, and disease regulation; *supporting* services such as biodiversity, soil formation and nutrient cycling that underlie the previous two services; and *cultural* services such as recreational, health, and aesthetic benefits (Millennium Ecosystem Assessment 2005). Over the last decades, the ecosystem services concept has been marshalled at various scales to quantify the economic value of natural capital (Costanza et al. 1997; Costanza et al. 2014), to bolster conservation efforts (Chan et al. 2006; Naidoo et al. 2008), and to assist in the valuation of environmental payment mechanisms and carbon markets (Farley and Costanza 2010; (Kinzig et al. 2011). Some of the most influential analyses have been done at the continental and global scale emphasizing natural capital and their contribution to global biogeochemical cycles (Millennium Ecosystem Assessment 2005). Criticism has been leveled against the ecosystem services approach, for instance how it strengthens market-based apolitical paradigms of environmental decision-making (Kosoy & Corbera 2010; Norgaard 2010) and provides too easy an entry point to engage with neoliberalism (Dempsey and Robertson 2012). These criticisms have some merit, especially since payments for ecosystem services schemes are typically imposed by international organizations like the World Bank on countries in the global south to further conservation goals at the expense of local and often already marginalized human populations. The touted financial gains are often unrealized and the schemes end up clashing with indigenous development goals (McAfee and Shapiro 2010). Regardless of these criticisms, the ecosystem services framework can be very useful, especially when trying to quantify a breadth of benefits that pass from the environment to humans.

Urban and neighborhood scale ecosystem services represent a unique and growing research topic (Bolund and Hunhammar 1999; Pataki et al. 2011; Gómez-Baggethun et al. 2013; Andersson et al. 2014), with subjects ranging from how urban ecosystem services improve resilience and quality of life (Gomez-Baggethun et al. 2013) to their impact on urban biogeochemical cycles (Pataki et al. 2011). A subset of urban ecosystem services research explores various aspects of public parks and urban green space. Urban green space is defined as a piece of publicly accessible land within a municipality's territory that has been set aside for recreational, environmental, or engineering purposes. Urban green space types fall on a "green-to-grey" continuum and includes land such as open space, city parks, green infrastructure, community gardens, tree rows, and vacant lots.

Ecosystem services research on urban green space has focused on ecological and economic topics such as health (Jennings and Gaither 2015; Jennings, Larson, and Yun 2018), the urban heat island (Feyisa, Dons, and Meilby 2014) planning and conservation (Niemela et al 2010; Kabisch 2015), community gardens (Middle et al. 2014; Speak, Mizgajski, Borysiak 2015) and monetary valuation (Jim and Chen 2009; Sutton and Anderson 2016). Due to the spatial nature of urban green space, examining the landscape distributional patterns of urban ecosystem services comes naturally. However, as important as the economic and ecological context are, few of them looked at the underlying social inequities of their provision.

Empirical research and review articles on urban green space have shown that public parks and open space are not allocated evenly in cities (e.g. Heynen, Perkins, and Roy 2006; Rigolon 2016). Green space access and use are often stratified along socio-demographic lines such as income, race, age, and gender – posing serious challenges and opportunities, for cities as they tackle sustainability, environmental quality, and social inequality. Despite a budding interest in the role of distributive justice in ecosystem service theory (Ernstson 2013; Sievers-Glotzbach 2013) there appear to be no studies that assess the uneven distribution of urban ecosystem services. This may be due to the social and ecological complexities inherent in each or to underlying epistemological differences between the two concepts (Ernstson 2013). Although it has had some success at national and the international policymaking scales, for the promise of the ecosystem services concept to succeed, it must be taken up by more regional and local planning entities (Daily et al. 2009; Rall, Kabisch, and Hansen 2015).

Most urban green space equity research has focused on user access through measures of *quantity*, especially proximity and acreage, while its *quality* is often overlooked. Green space research and planning tends to define park quality in one-dimensional ways – e.g. amenities, facilities, maintenance, safety (Rigolon 2016; Trust for Public Lands 2020) – despite demands from users that green spaces offer a range of environmental amenities (Boulton, Dedekorkut-Howes, and Byrne 2018). The ecologies of urban green spaces, although highly managed, are recognized in their own right as biodiversity hot spots (Cornelis and Hermy 2004; Nielsen et al. 2013; Aronson et al. 2017), novel ecosystems (Perring et al. 2013) and sites of important landscape ecological patterns and processes (Breuste, Niemela, and Snep 2008; Tian, Jim, and Wang 2014) such as greenway corridors (Jongman and Pungetti 2004; Kong et al. 2010). The ecosystem services framework can provide a multidimensional way of meaningfully quantifying urban green space (Lovell and Taylor 2013), especially since it considers human user needs by providing numerous social and cultural services (Daniel et al. 2012).

Ultimately, urban ecosystem services research needs a framework for understanding equity; just as green space equity research needs a multidimensional way of framing quality. These two research agendas complement each other and were used as a methodological guide for this study. Herein, ecosystem services are operationalized as a proxy measure of urban green space quality. Building on previous research of urban park and green space inequality, a major objective of this study is to determine if the quality of urban green space, as measured by its ecosystem services, follows the same distributional logic as green space quantity.

Methods

Study area

Despite obvious social and economic inequality in urban neighborhoods across the U.S., few studies have examined how public green space is distributed in those communities. This study is based in the Denver Metropolitan Area, a ten-county region in north central Colorado, U.S.A. situated along the eastern edge of the Rocky Mountains. It is a unique yet emblematic site to study the distribution of ecosystem services due to its proximity to national and state public lands, history of regional conservation, numerous open space parks within and surrounding the metropolitan area, active residents known for an appreciation for the outdoors, and racially diverse population. The Denver-Aurora-Lakewood Metropolitan Statistical Area (MSA) is one of the fastest growing regions in the U.S., with a total population of 2,967,239 – up 16.7 % from 2010. The MSA average rate of growth for the same period was 7.5 % (U.S. Census Bureau 2020b). The current population explosion creates significant social and environmental challenges in the areas of affordability, equity, mobility, and sustainability (Goetz and Boschmann 2018). As new development tries to keep pace with population, housing and infrastructure density is on the rise, with pressure mounting on the local natural environment.

The three largest municipalities in the MSA – Denver, Aurora, and Lakewood – were selected for this study. According to 2019 Census estimates, Lakewood is the least racially diverse, with nearly 70 % White residents (Appendix B). This suburban foothill

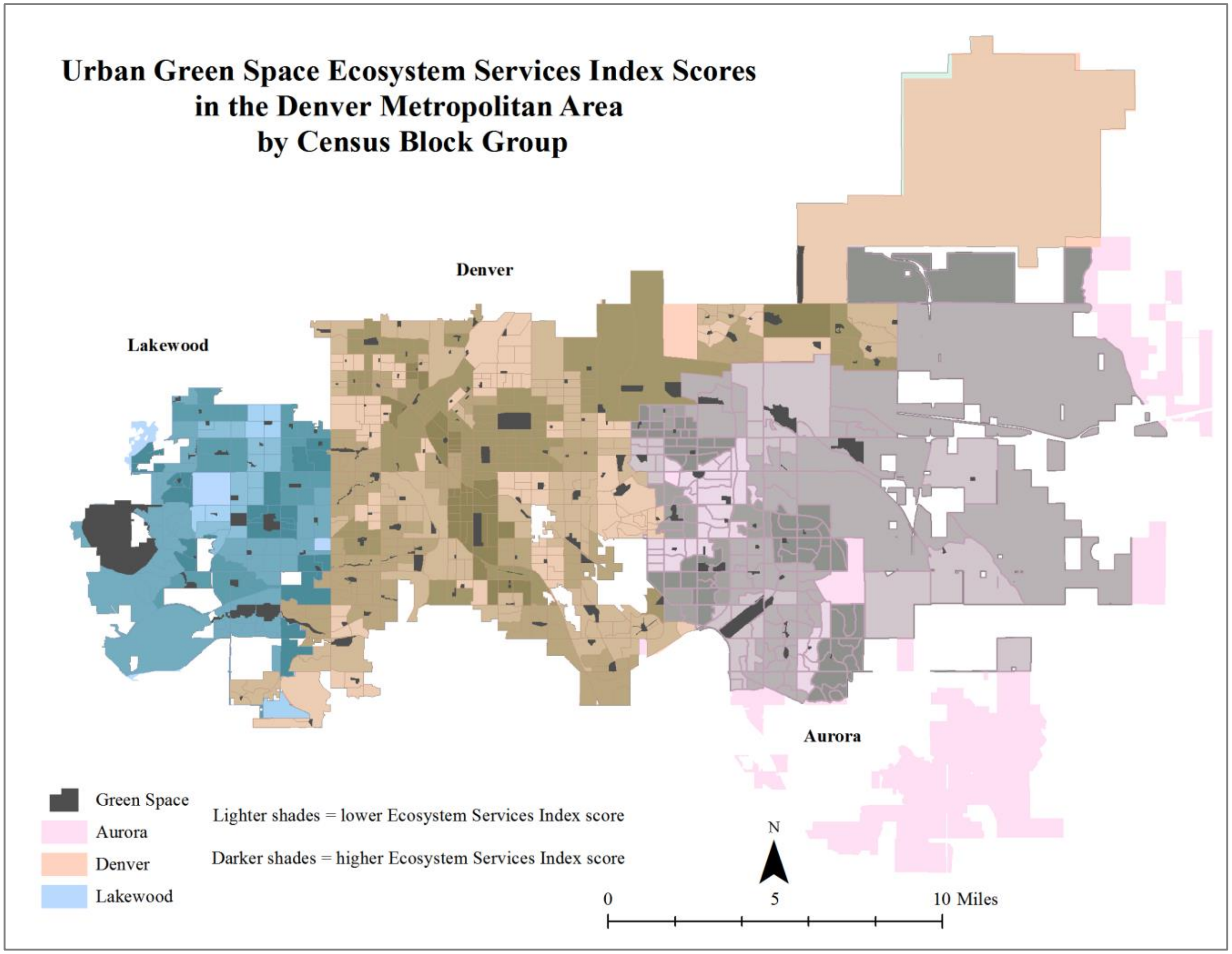


Figure 8 - Map of urban green space and White population in the Denver Metropolitan Area

city was incorporated in 1969 and is located west of Denver. Its green space configuration is dominated by the region's largest open space parks (Table 8), located in the western edge of the city near the mountains (Figure 8). Denver was founded in 1858 as a basecamp for gold mining expeditions into the Rocky Mountains. It grew as the central business district of the region and is now a major international economic hub for energy, defense, tourism, and recreation. Denver is considered a tri-ethnic city and is approaching racial parity between White and non-White residents, although its Black and Latino populations have experienced discrimination in housing and education, which are inscribed in the city's history through redlining and fights over busing (Goetz and Boschmann 2018). Even though Denver has the smallest parks and green spaces in the study area, averaging 13.06 acres, they appear to be uniformly configured across the landscape and dominated by several large urban parks in the older central core of the city. Aurora is the most racially diverse city in the study area, with its White population being in the minority. This "majority-minority" city is a national hot spot for immigration, with nearly 20 % of its population foreign born and twice as many people identifying as 2 or more races than the national average. It is home to various refugee-oriented community service organizations such as the Rocky Mountain Welcome Center, a non-profit offering community services that foster multicultural learning and integration among immigrants, refugees, and Colorado residents. Its green spaces are medium sized compared to the other two study sites and dominated by linear greenways that have a northwest-southeast directionality due to several rivers and streams that flow form the mountains to the plains.

Table 8 - Green space descriptive statistics

City	Area (Sq. Miles)	# of green spaces*	Green space area (%)	Green space avg size (acres)	# of green spaces visited
Denver	154.75	410	8	13.06	103
Lakewood	44.22	109	23	53.86	26
Aurora	158.82	435	11	23.07	31

*Excludes golf courses, cemeteries, reservoirs, state and federal parks.

Data collection and processing

The objective of this study was to statistically assess the quality of urban green spaces, as measured by their ecosystem services, against various social race, income and education indicators. The main components of this analysis were:

1. A unique field- and GIS-based ecosystem service index, which was derived from environmental and cultural data collected in the field and digitized from aerial imagery. Index scores were calculated for each selected green space.
2. Socio-demographic data obtained from the U.S. Census Bureau, at the census block group level.
3. Bivariate correlation analysis, which was the vehicle for establishing statistically significant associations.

Table 9 - Green space ecosystem services index components

Type	Ecosystem Service	Indicator	Metric	Data Source
Provisioning	Crop Production	Community gardens and farm plots	(area of garden plots ÷ (area of green space)	Field survey, GIS
Regulating	Carbon storage and cooling effect of vegetation	Tree cover	(# of trees per green space) ÷ (area of green space)	Satellite Imagery
	Water cycle regulation	Wetlands, Lakes, and streams	(area of water features) ÷ (area of green space)	Satellite Imagery, GIS
Supporting	Biodiversity	Species richness	# of vegetation species	Field survey
Cultural	Recreation	Trails	(Trail length) ÷ (area of green space)	Satellite Imagery, GIS
		Users	# of users	Field survey
		User activities	(# of user activities) ÷ (# of users)	Field survey
		Cultural amenities (historical, religious, educational, or artistic amenities); recreation centers were excluded	(# of amenities) ÷ (area of green space)	Field survey

Ecosystem services data

There are roughly 1,000 discrete green spaces across the three study sites (Table 8), covering a dozen green space types (Table 4). Due to time and resource constraints, 25 % of green spaces were selected for fieldwork. The largest green space inside each census block group was selected. A total of 160 green spaces were selected: 103 in Denver, 26 in Lakewood, and 31 in Aurora. Each green space was visited between 10:00 AM and 6:00 PM during mild weather conditions (55-85 Degrees F), and the following ecosystem service information was collected in situ on a data sheet (Appendix C and D):

- Provisioning: area (sq. ft) of community garden plots.
- Supporting: vegetation species richness was measured as an indicator of biodiversity. Two 5 x 25 foot long belt transects were used per green space – one located at the southwest corner on a north-south axis, and one located at the geographic centroid on an east-west axis. Google earth was used to pinpoint the exact location of the centroid transect.
- Cultural: the number of users, their activities, and number of cultural resources such as public sculptures, were noted. Recreation centers were excluded.

To round out the index, the following GIS features were digitized in ArcGIS 10.5 at a scale of 1:2500 or smaller, based on 1-meter resolution aerial imagery:

- Provisioning: area (sq. ft) of community garden plots and urban farms. This was used for large garden areas and to verify data collected in the field.

- Regulating: the number of trees were counted. polygons were drawn around bodies of water, including wetlands, lakes, and streams. During fieldwork, I noted if water bodies were present. I digitized their extent based on visual analysis at 1:1000 scale or smaller. I verified water features with Google Earth and made sure running water was year-round and not just seasonal. Lake islands were cut out of the polygons, creating donut features.
- Cultural: trail features were digitized. All sidewalk, bike, dirt, and impromptu trails were digitized at centerline. Sidewalks along green space boundaries were not digitized, unless they travelled into the green space.

Each component was calculated based on the metric column in Table 9. Each metric was standardized to form a score of 0 to 1 with the following equation:

$$Standardized\ metric\ = \frac{actual\ value - minimum\ value}{maximum\ value - minimum\ value}$$

The final ecosystem services index scores for each green space were then calculated by aggregating the standardized metrics for each of the ecosystem services variables and computing their mean:

$$ESI\ = \frac{I_{Crop} + I_{Water} + I_{Trees} + I_{Diversity} + I_{Trails} + I_{Users} + I_{Activities} + I_{Culture}}{8}$$

An index score of 0 represents a green space that provides no ecosystem service benefits. Lower scores will indicate less benefits; higher scores will indicate more benefits. I ran four ecosystem service models based on the equation above with slightly different parameters, and selected one for analysis that was the most normally distributed.

Social and demographic data

Social variables were calculated at the census block group level using data from the 2016 U.S. Census American Community Survey. Social variables included indicators of race, ethnicity, income, and housing. For race, percent White, Black, Asian, and Native American were used; for ethnicity, percent Hispanic. For income, per capita income and median household income were used. For education, percent without a high school diploma and percent with a bachelor's degree or higher were used. For demographics, gender and median resident age were used. Since green spaces and their attendant ecosystem services are embedded in the urban landscape the following land use variables were used: median year built, median home value, population density, and distance from central business district.

Combining the ecosystem services data with the social data

Once the ecosystem services indices were calculated for each of the 160 green spaces, the scores were then transferred to census block groups using the following criteria: census block groups that fully contained, intersected with, or were within .5 miles of a green space received its ecosystem service score; in locations where there wasn't enough green space coverage, mainly suburban and rural areas, I expanded my search area to 1 mile; if there were no green spaces within 1 mile away of the census block, the census block was discarded from the final analysis.

Statistical analysis

The primary objective of this research was to investigate the associations between green space ecosystem services on the one hand and neighborhood racial, income, and demographic makeup on the other. Bivariate correlation analysis has been a common tool in environmental justice research (Schwarz et al. 2015). It extends basic equity mapping techniques (Talen 1997 and 1998; Wolch, Wilson, and Fehrenbach 2005; Rigolon 2017) with statistical inferences that help establish statistically significant baseline disparities in the allocation of environmental amenities. For this study, bivariate Pearson correlation and Spearman's non-parametric correlation were used as simple aspatial indicators of association between the ecosystem services index variable on the one hand, and socioeconomic and land use variables on the other (e.g. high values in one dataset match high values in another). Spearman's rho is a rank-order correlation for use with non-parametric data. All correlation analyses were calculated in SPSS Version 17.0.

Data and research limitations

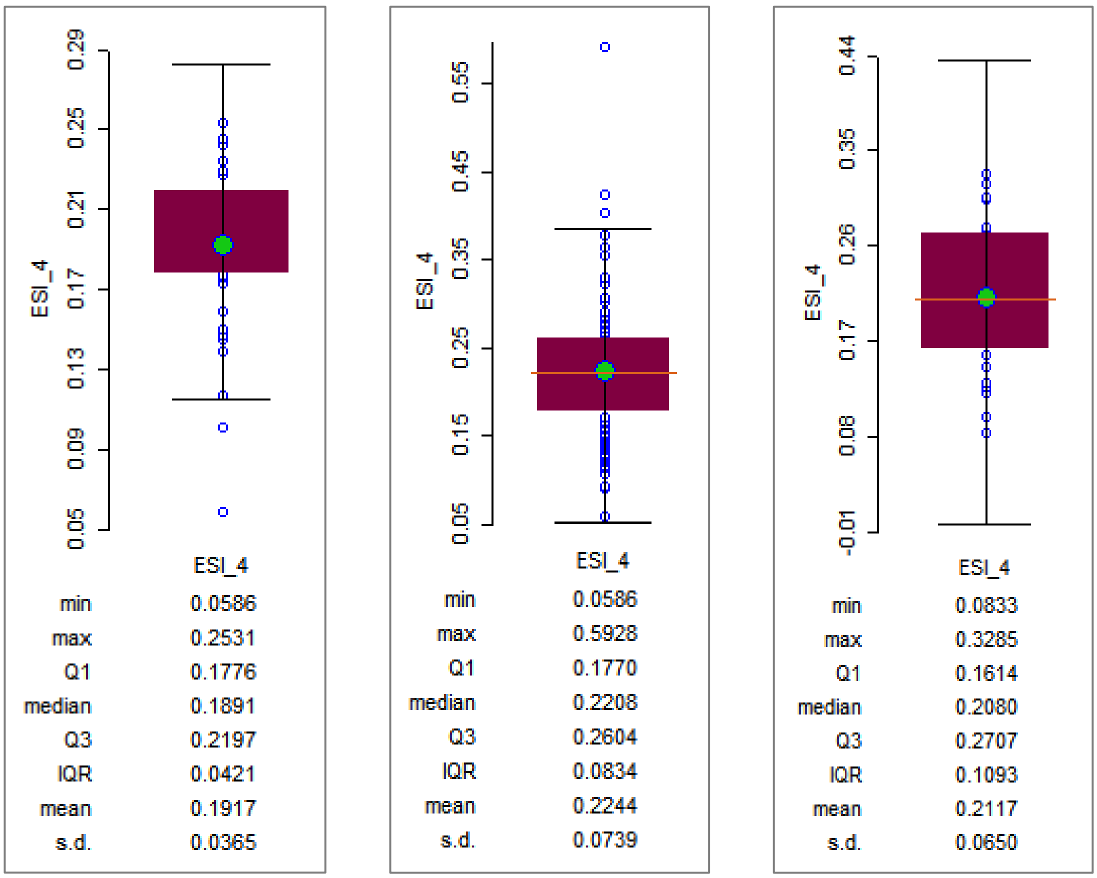
1) Due to research constraints, I was not able to finish fieldwork at ten green spaces. Most of them were all in the southeast corner of Aurora, so I left their surrounding census block groups out of the correlation analysis[4]. This may change the correlation results, especially in Aurora. 2) In order to convey green space user preference in the index, I intended to perform intercept surveys at every green space. After several attempts, I realized this would have doubled or tripled the amount of time spent at each green space, making it time prohibitive; I cut the user survey component. 3) There could have been bias in transferring ecosystem service scores from green spaces to census block groups. I tried to minimize this with the above criteria, but it was not an automated process. 4) I

[4] Prior to submitting this article to a journal, I will complete the fieldwork, recalculate the ecosystem services indices, and rerun statistical analyses.

was not able to capture large rivers as water features, because they were rarely inside green space boundaries. For example, the South Platte river runs adjacent to Denver's Ruby Hill and Globeville Landing parks but falls outside their boundary. 5) Tree canopy data was not available for all the study sites, neither was it feasible to digitize manually. Counting trees one-by-one per green space was an adequate solution, but no distinction was made between young and mature trees. 6) Ecosystem disservices, such as application of pesticides and the environmental and financial costs of maintenance were not quantified in the study. If they would have been, the ecosystem services scores may have been lower, and perhaps influenced the correlation results. 7) Like any research that includes sampling, the data is only as good as the time and day it is collected. Some index components, such as number of users, are highly variable throughout the day, especially in green spaces with ballfields during active sports seasons. Although this could impact the final ecosystem service index score, this problem is somewhat ameliorated since each index component is normalized before its final calculation.

Results

Correlation analyses suggests that some city's green space ecosystem services in the Denver Metropolitan Area are more evenly distributed than others (Figure 10). Although the R scores were all somewhat low, these are still fairly significant results, especially for environmental justice studies like this that combine social and environmental variables (Schwarz et al. 2015). Descriptive statistics show that Denver's census block groups have the highest ecosystem service scores in the study area. This means that the green spaces in Denver provide relatively more ecosystem services than the green spaces in Lakewood or Aurora. Not only does Denver have the highest overall score of .5928, it also has the highest mean (.2244) and standard deviation – i.e. the greatest range of scores (Figure 9). Lakewood had the lowest scores (mean = .1917); its green spaces provide the least amount of ecosystem services. Aurora's mean score was .2117.



Lakewood Denver Aurora

Figure 9 - Descriptive statistics for the three study sites

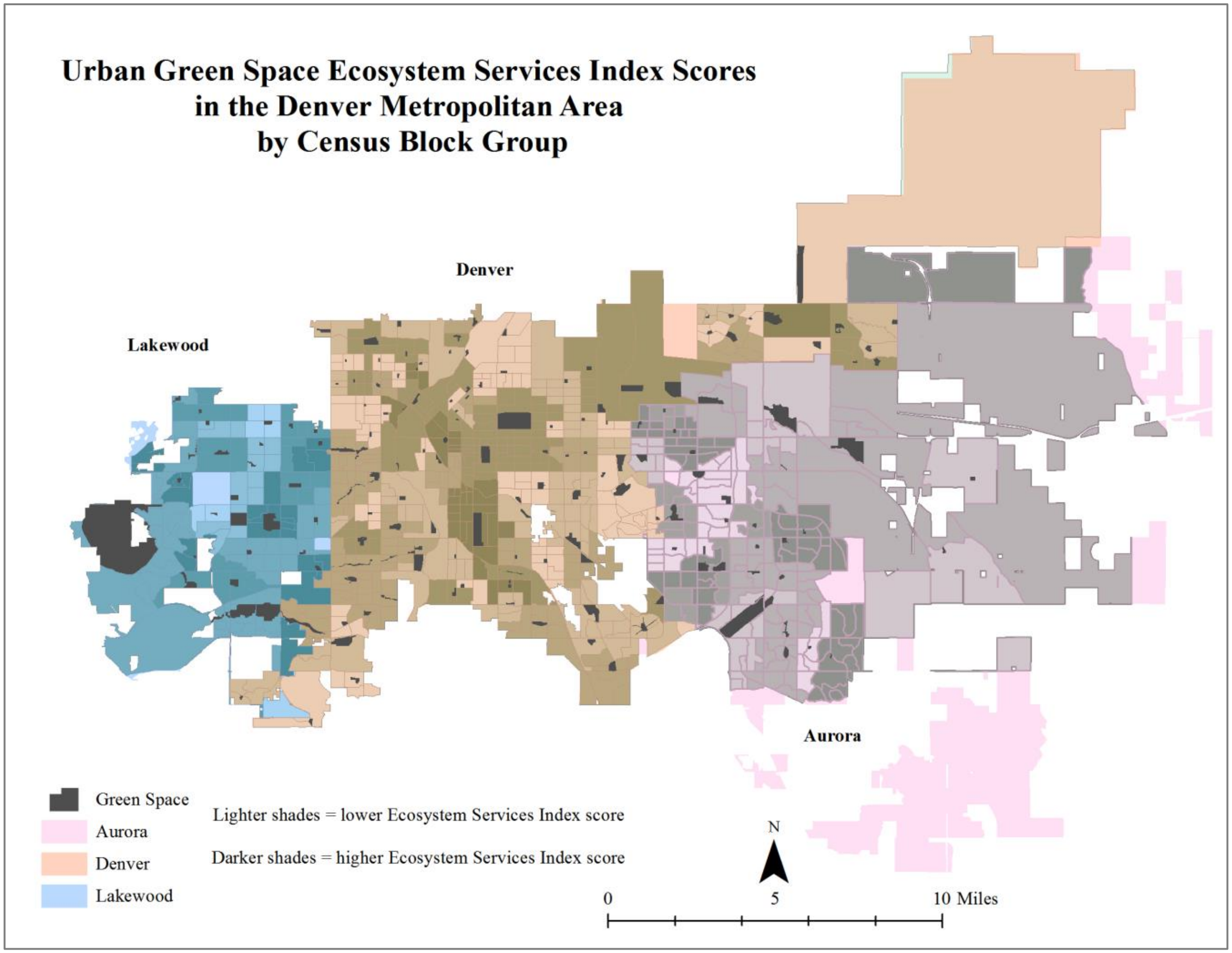


Figure 10 - Map of the green space ecosystem services scores across the Denver region

For *Lakewood*, all bivariate correlations were rather weak across the board, showing only minor statistical relationships among the variables (Table 10, Figure 11). Nevertheless, there is an interesting pattern. The green spaces in predominately White neighborhoods with higher home values provide less ecosystem services than Hispanic and Black neighborhoods, as seen in the maps in Figures 10 and 12.

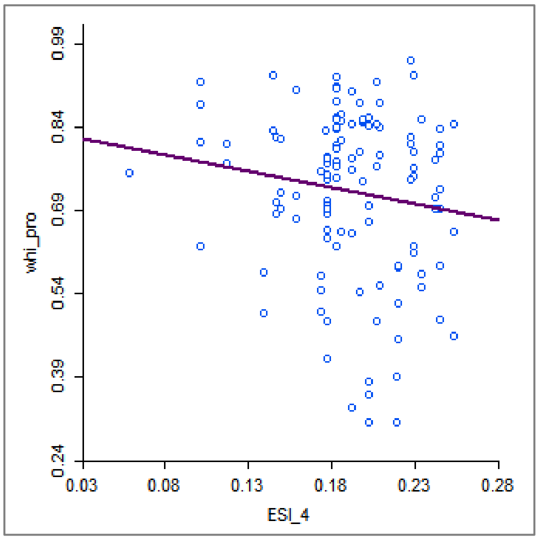
Table 10 - Ecosystem services index correlations for Lakewood

	Pearson Correlation		Spearman's rho (non-parametric)	
Variable	**R**	**Sig**	**R**	**Sig**
Proportion White	-0.144		-0.072	
Proportion Hispanic	0.151		0.098	
Proportion Black	0.116		0.028	
Proportion Native American	-0.092		-0.223	*
Proportion Asian	-0.061		-0.106	
Proportion Female	-0.074		-0.128	
Proportion Male	0.074		0.128	
Median Resident Age	-0.069		-0.042	
Proportion No HS Diploma	0.071		0.093	
Proportion Bachelors or Higher	-0.023		0.012	
Per Capita Income	0.021		0.094	
Median Household Income	-0.038		-0.030	
Median Year Built	0.039		0.203	*
Median Home Value	-0.146		-0.061	
Population Density	0.094		0.101	
Dist from CBD	-0.097		-0.089	
n (census block groups)	122		122	

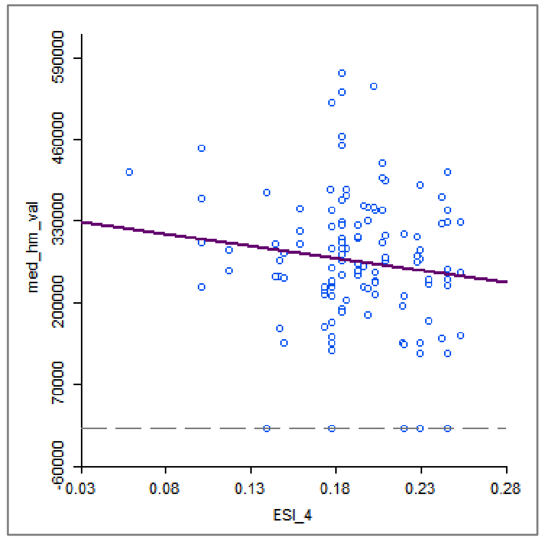
0.6	0.5	0.4	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

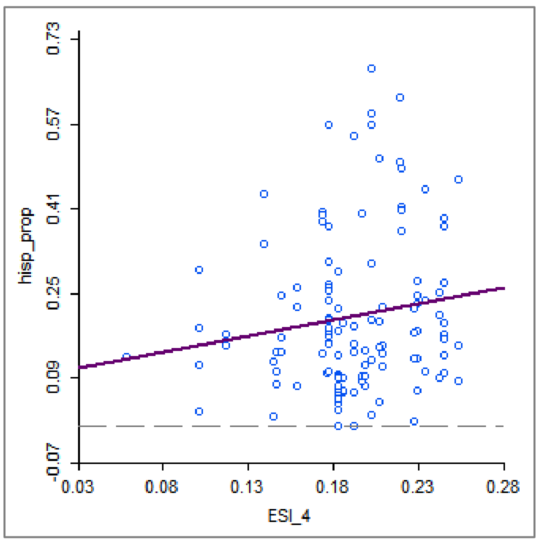
Newer neighborhoods and areas with more males are correlated with higher ecosystem services. Census block groups with a relatively high percentage of Native American and Asian populations are correlated with lower ecosystem service scores.



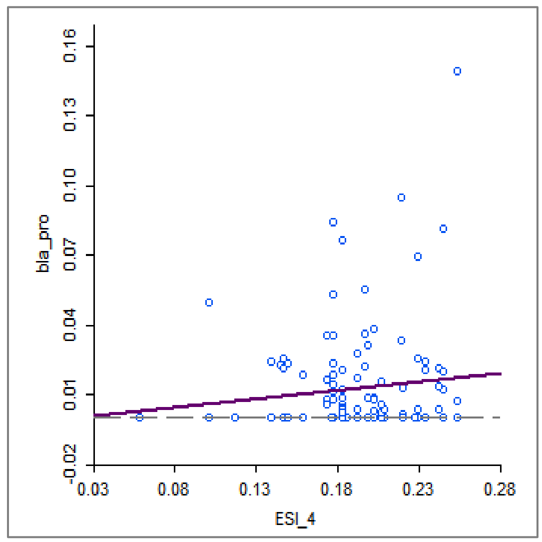
Proportion White



Median Home Value



Proportion Hispanic



Proportion Black

Figure 11 - Bivariate scatter plots of ecosystem services index for Lakewood.

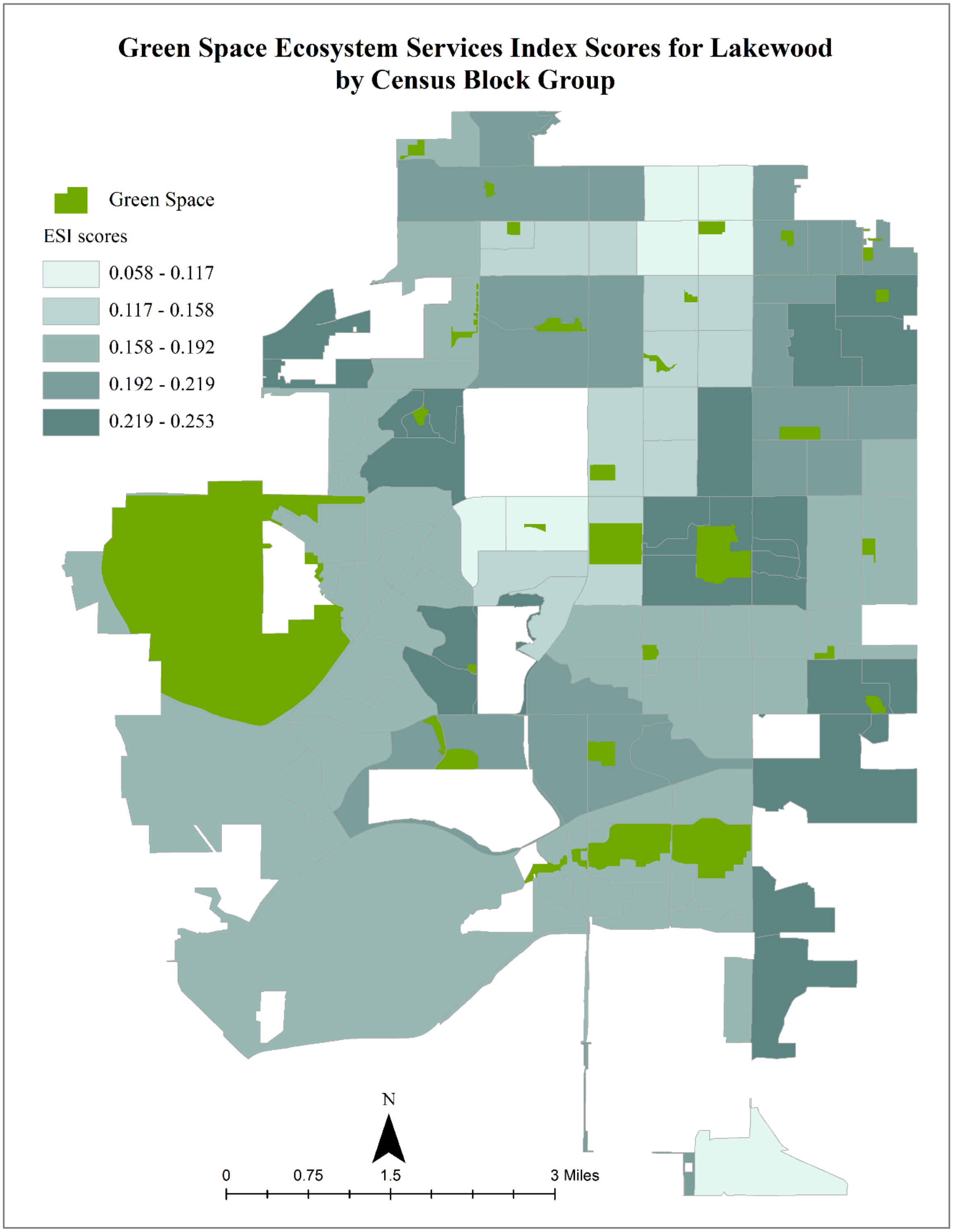


Figure 12 - Map of the green space ecosystem services scores for Lakewood

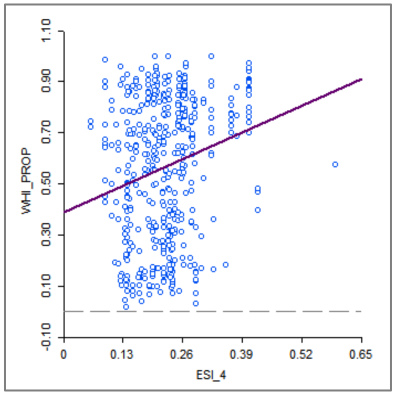
For *Denver*, statistically significant racial, gender, education, and income disparities are present. As seen in Table 11 and Figures 13 and 14, census block groups with predominately highly educated and White populations live in neighborhoods with high quality green spaces that provide the study area's most ecosystem services. Whereas Hispanic and Black populations tend to live in neighborhoods with green spaces that provide relatively few ecosystem services. Education and income, although likely correlated with each other, are also associated with higher index scores. A surprising but noteworthy result is

Table 11 - Ecosystem services index correlations for Denver

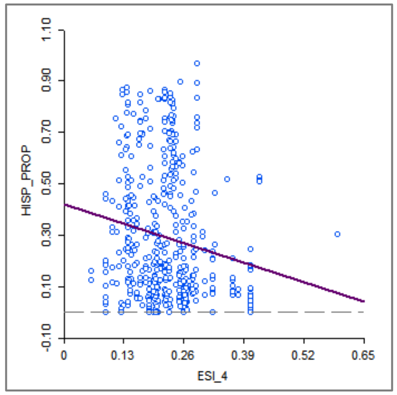
	Pearson Correlation		Spearman's Rho (non-parametric)	
Variable	**R**	**Sig**	**R**	**Sig**
Proportion White	0.215	**	0.210	**
Proportion Hispanic	-0.170	**	-0.186	**
Proportion Black	-0.130	**	-0.124	**
Proportion Native American	-0.046		-0.052	
Proportion Asian	0.017		0.051	
Proportion Female	-0.163	**	-0.142	**
Proportion Male	0.163	**	0.142	**
Median Resident Age	-0.076		-0.053	
Proportion No HS Diploma	-0.188	**	-0.185	**
Proportion Bachelors or Higher	0.264	**	0.245	**
Per Capita Income	0.179	**	0.191	**
Median Household Income	0.078		0.085	
Median Year Built	-0.017		-0.167	**
Median Home Value	0.187	**	0.197	**
Population Density	0.121	**	0.144	**
Dist from CBD	-0.240	**	-0.278	
n (census block groups)	480		480	

0.6	0.5	0.4	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6

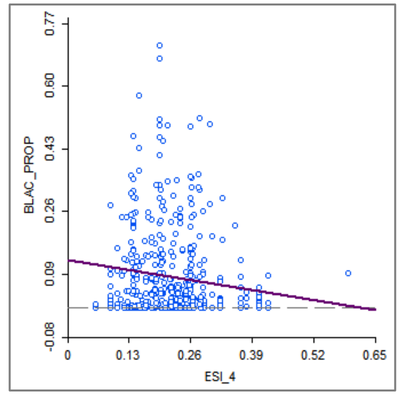
*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).



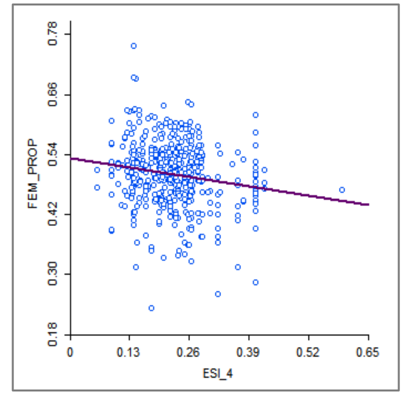
Proportion White



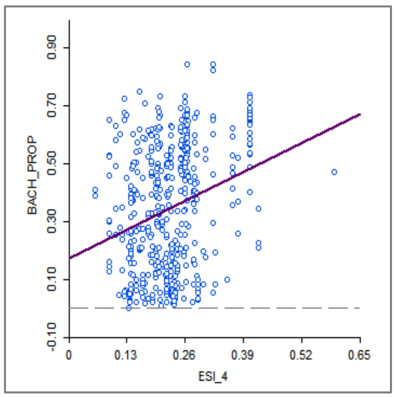
Proportion Hispanic



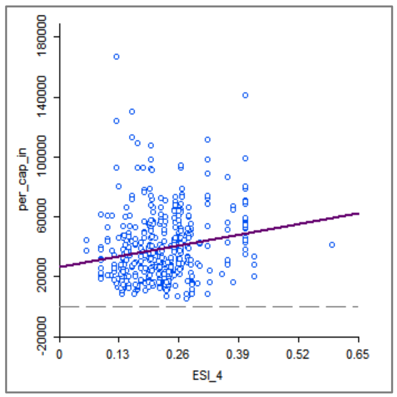
Proportion Black



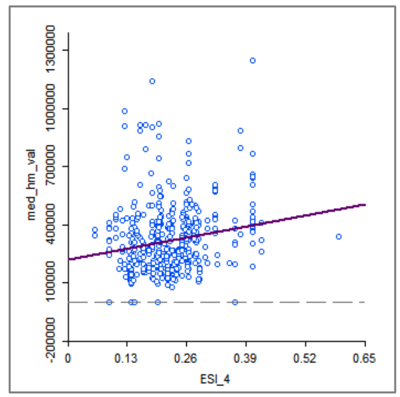
Proportion Female



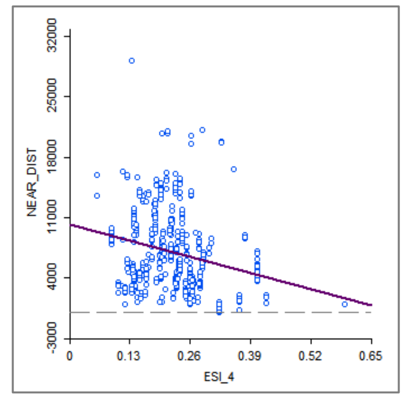
Proportion Bachelors or higher



Per capita income



Median home value



Distance to CBD

Figure 13 - Bivariate scatter plots of green space ecosystem services index for Denver

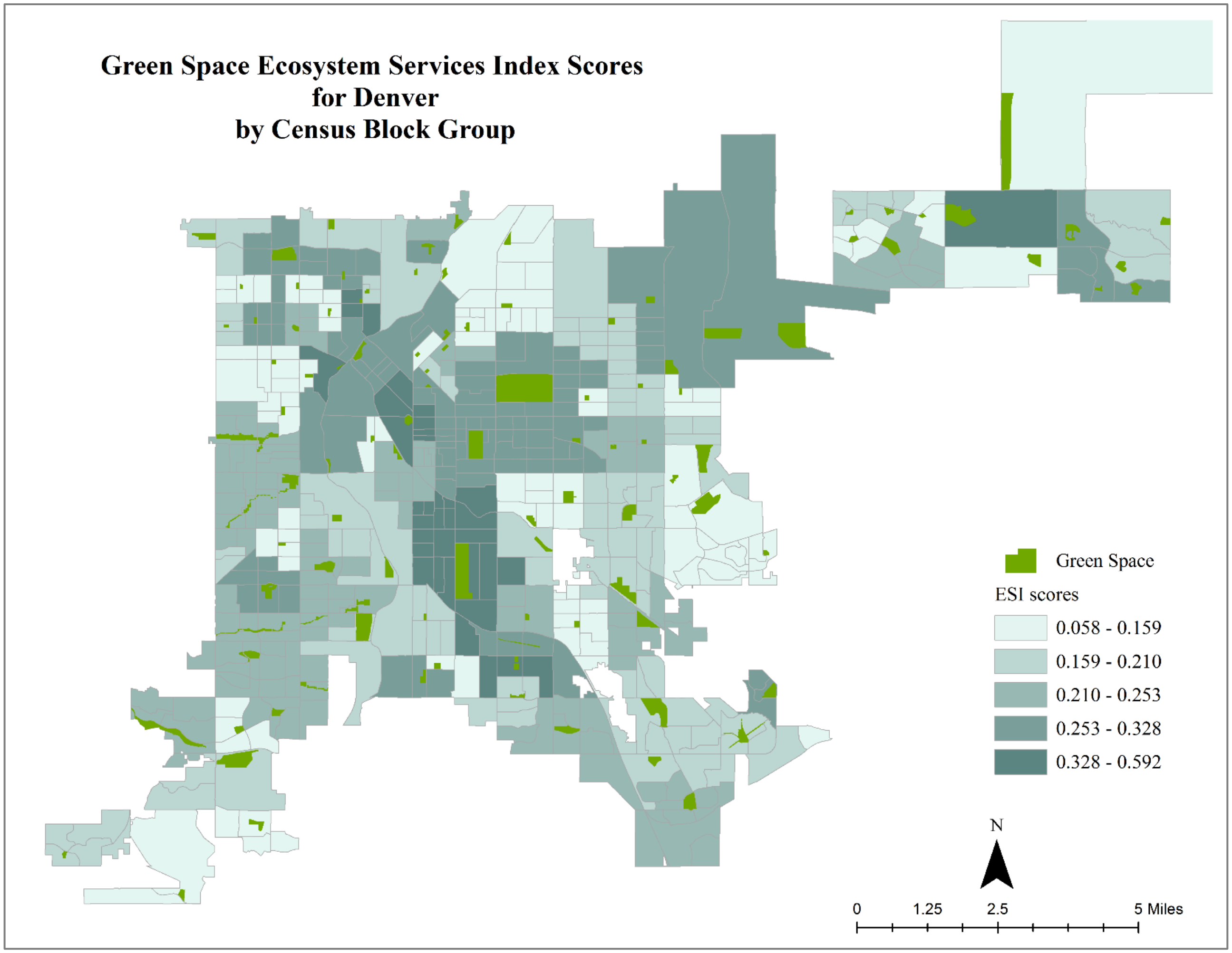


Figure 14 - Map of the ecosystem services scores for Denver

that neighborhoods with a high concentration of females have statistically less access to high quality green spaces than males. As for land use characteristics, median home value and population density are correlated with high value green spaces, and low value ones appear to be in neighborhoods far from the central business district (CBD).

For *Aurora*, there are just a few statistically significant correlations (Table 12 and Figure 15). There are very weak negative correlations between Hispanic and Native American populations and high levels of green space ecosystem services. While there are weak positive correlations for Black and Asian populations. The most significant finding here is that Asian populations appear to live in neighborhoods that have the highest quality green spaces in all of Aurora. In contrast to Denver's results, distance from CBD is positively correlated with high ecosystem service index scores, meaning that outlying neighborhoods have relatively high-quality green spaces. As can be seen from Figure 16, Aurora has relatively large census block groups in its eastern section where there are a lot of greenways and open space parks.

Discussion

Correlations between the distribution of green space environmental benefits and socio-economic variables vary widely across the Denver Metropolitan region. As noted above, Lakewood and Aurora appear to have the least amount of disparity, and one of the most striking patterns in the data is the positive relationship between the ecosystem service index score and White populations in Denver. As seen in the Denver map below (Figure 17), many of the whitest neighborhoods in Denver are home to the highest

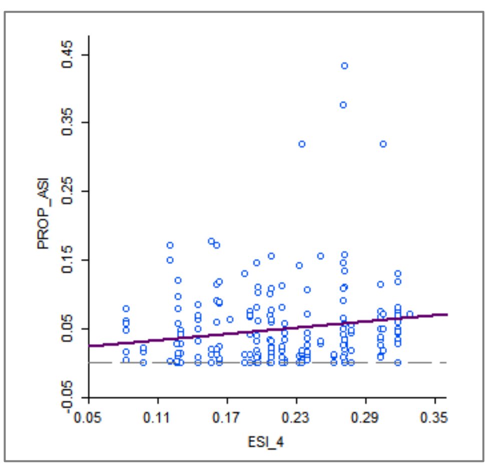
Table 12 - Ecosystem services index correlations for Aurora

Variable	Pearson Correlation R	Pearson Correlation Sig	Spearman's Rho (non-parametric) R	Spearman's Rho (non-parametric) Sig
Proportion White	0.003		0.000	
Proportion Hispanic	-0.070		-0.069	
Proportion Black	0.033		0.061	
Proportion Native American	-0.069		-0.032	
Proportion Asian	0.163	*	0.190	**
Proportion Female	-0.065		-0.038	
Proportion Male	0.065		0.038	
Median Resident Age	-0.021		0.024	
Proportion No HS Diploma	0.013		-0.008	
Proportion Bachelors or Higher	-0.017		0.023	
Per Capita Income	0.029		0.040	
Median Household Income	0.083		0.077	
Median Year Built	-0.039		0.046	
Median Home Value	-0.009		0.033	
Population Density	-0.024		0.023	
Dist from CBD	0.171	*	0.135	
n (census block groups)	207		207	

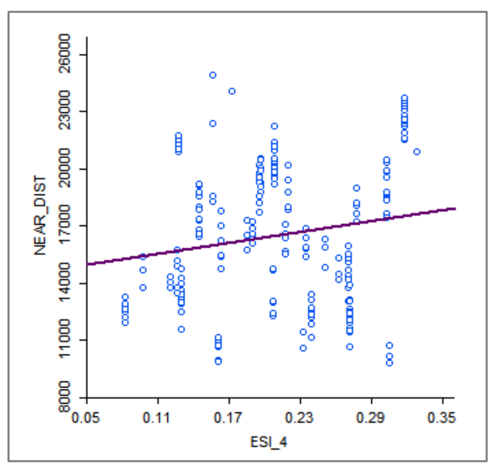
0.6	0.5	0.4	0.3	0.2	0.1	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6

*Correlation is significant at the 0.05 level (2-tailed).

**Correlation is significant at the 0.01 level (2-tailed).



Proportion Asian



Distance to CBD

Figure 15 - Bivariate scatter plots of green space ecosystem services index for Aurora

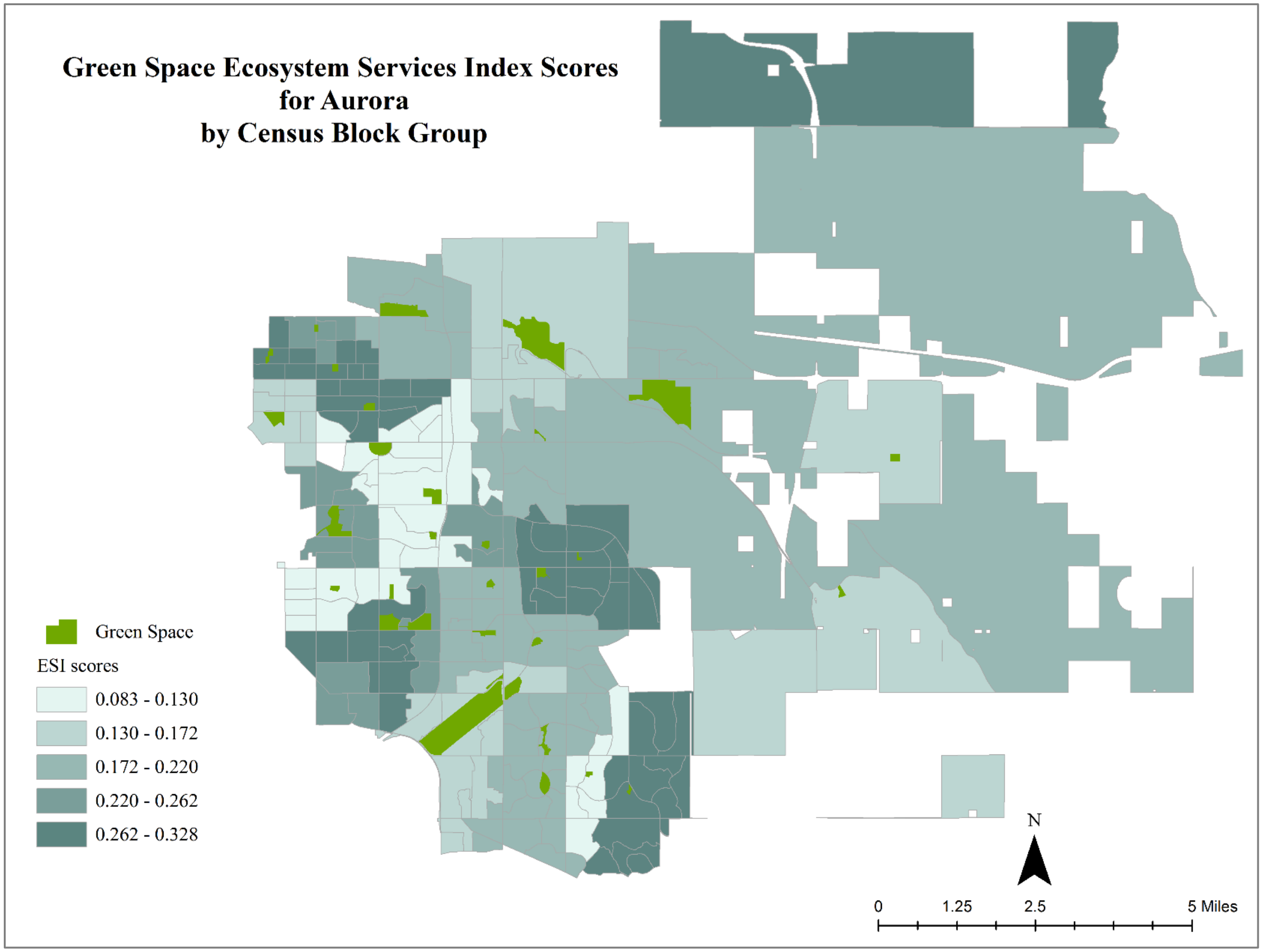


Figure 16 - Map of the ecosystem services scores for Aurora

ecosystem service scores. Related, many of the Hispanic neighborhoods are in the western and northern parts of the city where the quality of green spaces is spotty.

These disparities are born out in the ecosystem services provided by the various green spaces across the study area. The table below summarizes components of the ecosystem services index for each study site (Table 13). Lakewood's green spaces are relatively high in ecological features such as biodiversity, trees, and water. However, many of the index components were normalized by area (e.g. trees and water), which means that its scores ended up being relatively low. This was due primarily to the large open space parks located in its western edge along the foothills. The neighborhoods in this area are predominately White and higher income, which explains the general negative correlation between ecosystem service scores and White populations for Lakewood.

Denver's green spaces have average ecological and cultural features, but it ended up having many of the highest scoring green spaces because of high user counts and relatively small green spaces. Aurora has the least amount of ecological and cultural features, has slightly more trails than Denver, the highest average number of users and user activities, and far fewer cultural amenities than Lakewood or Denver. The high number of users comes from a couple of outliers. One green space I visited was a ballfield park where several tournaments were happening; I counted nearly 1,000 users. This brings up a data limitation issue, in that some of these results may be biased toward green spaces where there was an inordinate number of users on the day I visited. This problem was somewhat solved by normalizing user data by green space area, but it still may have an outsized influence on results. The only cultural amenities noted in my fieldwork for Aurora were public sculptures.

Table 13 - Ecosystem services of green spaces in Lakewood, Denver, and Aurora

Ecosystem Service Component (per Green Space) *		**Lakewood (n = 26)**	**Denver (n = 103)**	**Aurora (N=31)**
Crops (Sq. Ft)	Min	0	0	0
	Max	17000	50000	11000
	Mean	658.76	599.37	364.64
Trees (Number)	Min	12	17	3
	Max	1342	1444	1207
	Mean	186.69	177.89	170.51
Water (Sq. Ft)	Min	0	0	0
	Max	756995	1576223	434514
	Mean	77192	66724	46505
Biodiversity	Min	1.5	1	1
	Max	10.5	10.5	10.5
	Mean	5.09	4.5	4.46
Trails (Linear Ft)	Min	0	0	0
	Max	183002	71836	37605
	Mean	14568.71	6506.34	6971.81
Users (Number)	Min	0	0	0
	Max	183	359	937
	Mean	27.38	36.31	66.09
User Activities	Min	0	0	0
	Max	7	13	9
	Mean	3.5	4.39	4.87
Cultural Amenities (excludes recreation centers)	Min	0	0	0
	Max	3	4	2
	Mean	0.42	0.36	0.29

*The ecosystem service index uses area- and user-normalized components; the numbers in this table are non-normalized.

Green space feedback loops

Denver clearly has the highest index scores and greatest disparities in access to the ecosystem services that green spaces provide. But what drives these disparities in Denver? The relationship between ecosystem service delivery and race in Denver may be the result of feedback loops, where high quality parks in White neighborhoods increase property values, attracting more White households. This positive feedback loop may support the maintenance of neighborhood green spaces as household income and levels of home ownership increase (Schwarz 2015). One of the highest scoring green spaces in Denver was Washington Park, whose surrounding census block groups are 85-95 % White with median home values ranging from $400,000 to $1,250,000. Conversely, areas with lower quality green spaces may have lower surrounding property values and be home to renters and residents on fixed incomes who are less likely to actively use green spaces. This could lead to further negative feedback since green space has been shown to significantly moderate stressful life events and health complaints (van den Berg 2010). On the other hand, residents in lower income neighborhoods with less quality green space might reasonably resist green spaces with better ecosystem services to avoid rising rents and gentrification (Wolch, Byrne, and Newll 2014).

Heterogeneous landscapes and ecosystem services mismatch

This study focused on disparities of race, income, and other characteristics of social status as the variables of concern. While these are important, especially in the case of Denver, land use variables such as population density, median year built, and distance from the downtown area often had higher r values. Cities are heterogenous landscapes

(Grimm et al 2000), as are the neighborhoods and green spaces embedded in them. This underlying unevenness may account for some of the inequitable distribution of the green space services. Other land use / land cover variables could be added to refine the correlation model such as impervious surface, urban morphology, housing density, vegetation indices, and urban tree canopy (Schwarz 2015).

This study is a comparison of the current components of ecosystem services and their delivery to current residents. However, green spaces are composed of sometimes prehistoric landscape features such as wetlands and long-lived organisms such as trees. In contrast, the social structure of cities can change rapidly. Recent studies have described how the current residential landscapes we observe today are legacies of past homeowner preferences and consumer habits (Boone et al. 2010). As such, present day green spaces and their ecosystem services may reflect past social characteristics, more than current ones. Quantifying and assessing current distributions and potential disparities associated with ecosystem services is imperative, but it is also important to bear in mind that present day patterns could be the result of inherited landscapes and legacies of formal and informal have left indelible patterns of social and environmental inequalities.

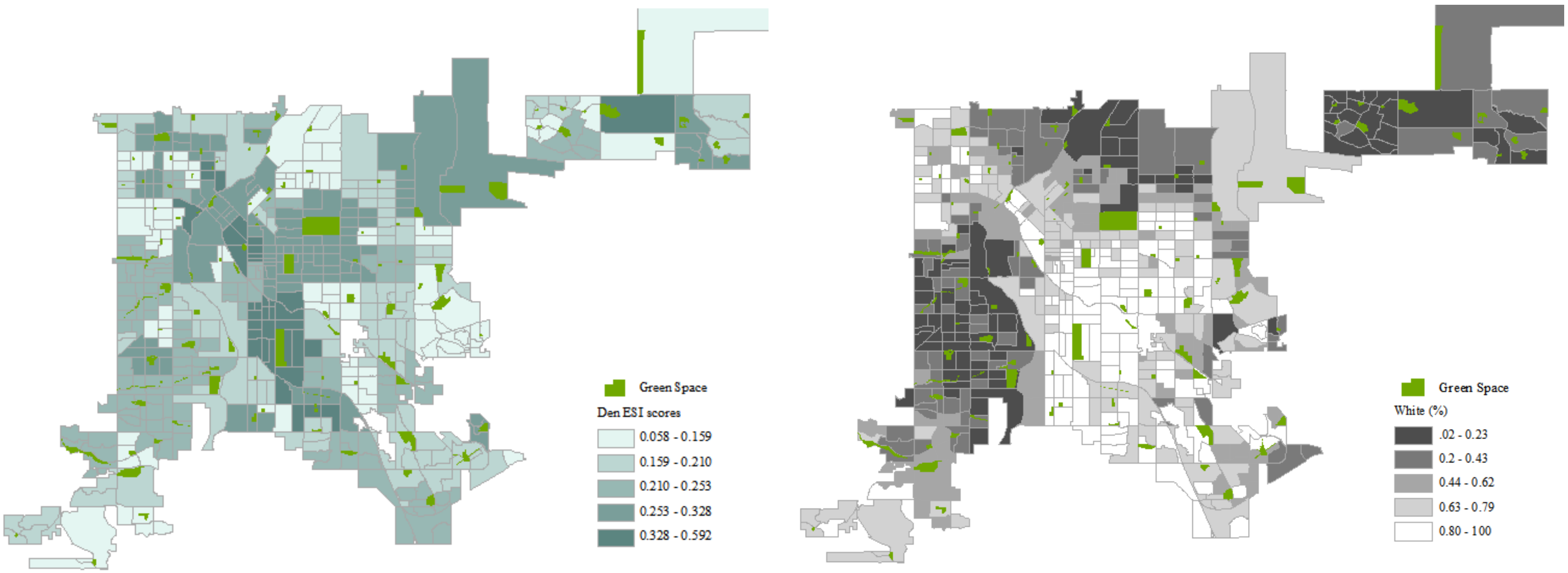


Figure 17 - A spatially-explicit map depicting the green space ecosystem index scores (left panel) and the percent of population that self-identifies as White (right panel)

Conclusion

Urban green space provides environmental, social, health, and economic benefits. Green space and the ecosystem services it provides are considered pure public goods, outside conventional financial markets. They are commons that are open to all and should be provisioned equally in cities. A main objective of this chapter was to determine if green space quality in the Denver Metropolitan area follows the same distributional logic as its green space quantity. Using a unique ecosystem services index based on field survey and GIS features as a multidimensional proxy for quality, I found that correlations between green space quality and socio-economic variables vary widely across the study area, but a clear pattern emerged, especially in Denver. Its census block groups have the highest ecosystem service scores in the study area, and the results showed statistically significant racial, gender, education, and income disparities.

This study was framed by the promise of utilizing the ecosystem services framework to fill gaps in green space equity research. I believe this project proved that the framework can be a very useful tool for human-environmental research, an integrative way to measure both ecological quality and human benefits. Most existing literature uses crude measures of quality such as park facilities, levels of maintenance, crime, and safety (Rigolon 2016). These one-dimensional properties do not and cannot capture the full variety of ecological affects and human-cultural responses to green space. Further study is needed to refine the ecosystem services framework and tailor it to green space equity research.

Chapter Five: The Green Divide: Case Studies from Denver, Colorado

Introduction

> The pride of Denver's summer season, the glory of the gardens of the plains and the valleys in the mountains, greener than any other green in nature, are their lawns. They are the envy of neighboring cities, for nothing elsewhere can equal the velvety irrigated bluegrass in the mile-high sections of the Denver region. Not in emerald Ireland, not in beautiful Holland, not in the east nor in the Pacific west are the greens as green. Set in the grays and browns of the dry prairies, and on the arid slopes of the foothills, here they are, kept by man's effort, maintained in the very face of nature's laws. They are like green jewels in a setting of silver and gold.
>
> -S. R. De Boer (1948), Denver park designer 1910-1931

Urban parks, green space, and other nature-based amenities provide numerous benefits to urban residents. These include health and psychological benefits, environmental services such as regulating air quality and protecting drinking water, cultural benefits from recreation and spiritual connections, and community cohesion. Urban green space makes cities vibrant and desirable places to live. Yet it is often allocated unevenly, according to social factors such as race, income, and education. Dozens of empirical studies from the fields of urban geography, urban planning, and urban political ecology have begun to provide evidence of these spatial disparities. The concept of environmental privilege is a relatively new concept which can be a useful framing device to analyze urban green space. Building up over time, privileges get inscribed in neighborhoods by the vicissitudes of urban morphology, by the ebb and flow of homes and businesses, residents and workers. Often without notice or fanfare, people find themselves on the wrong side of the tracks, sometimes for generations. Some privileges are new and obvious, constructed out of steel and girders, bike paths and greenways. The gleaming enclaves of new downtown residential towers provide sustainability amenities and lush green spaces, but too often lower-income and minority residents will never be able enjoy their benefits, except when passing by.

Environmental privilege is defined as the disproportionate access to green space, fresh food, healthy housing, playgrounds, and green infrastructure services from which higher income and White populations benefit while marginalized groups are excluded (Park and Pellow 2011; Anguelovski 2016). Davis and Moctezuma (1999) discuss an extreme case of this “green privilege”. Upset in the face of an influx of new immigrants to their city, White residents in San Marino, California, pushed their city council to introduce a weekend user fee of $12 for nonresidents to access one of the city’s nicest parks. This charge limited working-class Latino families’ access, while local wealthy White residents secured entry. Wealthy residents tend to enjoy green and healthy urban environments, at the expense of lower-income residents and people of color whose neighborhoods are often less green and prone to pollution.

As spatial-analytic and human geographers have tried to understand parks and urban green space inequity, in order to understand their social and historical context, they have engaged with environmental justice scholarship. At the same time, environmental justice activists and scholars have started to reconceptualize sites of injustice from environmental hazards like toxic waste dumps to environmental amenities like green spaces (Boone et al. 2009) and grocery stores (Alkon and Agyeman 2011). Through this admixture, a new form of green space research has formed that emphasizes the spatial components of green space equity, while not washing over its historical and cultural contexts.

Critical geographers and political ecologists, with innate interests in social inequality and Marxian interpretations of the city (Harvey 1973; Heynen 2013) have brought their political-economic perspectives on urban planning and sustainability to bear on green space inequity research. An important first step in understanding current green space patterns is reading the city through the lenses of historical injustices such as segregation, redlining, modern zoning. Another is to investigate urban sustainability programs, which may not be taking into account the third “E” of sustainability, equity. As certain urban districts become more desirable and expensive, premiums are placed on neighborhoods with amenities such as walkability, public transit, farmers’ markets, and green spaces. This raises the cost of living in those neighborhoods, pushing existing residents out. The marriage of urban redevelopment with green sustainability initiatives creates a paradox (Anguelovski et al. 2019). While urban greening programs provide ecological, social, and economic benefits to many urban residents, they may also create new and deeper vulnerabilities for some (Anguelovski et al. 2019). The shadow of green gentrification raises questions for urban sustainability and planning, of which this chapter raises some new questions, and proposes a few solutions.

As shown in previous chapters, the distribution of green space resources is highly uneven across racial/ethnic communities in the Denver Metropolitan Area. This chapter focuses on the largest and most populous city in the region, Denver. The first section examines a green space which had one of the highest ecosystem services index scores, which happens to one of the most popular urban parks in Denver, located in one of its most desirable neighborhoods: Washington Park. The second section examines two of the least performing green spaces according to my ecosystem services fieldwork. They are in one of the poorest neighborhoods with a high percentage of people of Hispanic heritages in the city, which has a history of redlining and is one the most polluted areas in the country: Elyria Swansea. The third section is an examination of two of the highest scoring green spaces and their surrounding up-and-coming neighborhoods which are currently undergoing green gentrification: Union Station.

Methods and Exploratory Spatial Data Analysis

This chapter examines various aspects of urban green space inequities at the neighborhood level in Denver, CO. I use results from the above ecosystem service index survey to locate neighborhoods of interest, perform exploratory spatial data analysis, analyze patterns, and interpret results. Specifically, I use a case study design to analyze critical aspects of green spaces in Denver neighborhoods. Using percentile and quartile social equity mapping techniques, I compared census block groups with high-quality green spaces to socioeconomic status, race/ethnicity, and housing affordability.

Green space quality was based on ecosystem services index scores, which were derived from in situ data collection and heads-up digitizing of landscape features in a GIS. Participant observation and visual landscape analysis was performed and noted. Index inputs included: community and school gardens (provisioning services); quantity of trees and water area (regulating services); species richness (supporting services); and length of trails, number of users and their activities, and cultural amenities such as public sculptures (cultural services). The ecosystem services index scores for each green space – ranging from .06 to .59 – were transferred to their surrounding census block groups (see chapter 3 and Table 9 for more information).

Socioeconomic status, race/ethnicity, and housing affordability data were collected at the census block group level from the U.S. Census bureau and American Community Survey (U.S. Census Bureau 2020). In order to detect how neighborhoods have changed over the years, I calculated demographic change values based on the difference between the 2000 and 2016 census datasets. This allowed me to map and analyze neighborhoods that are undergoing social or racial transition and potential sites of gentrification. Data were processed, analyzed, and mapped in ESRI's ArcGIS (Version 10.5) and the opensource spatial data analysis software package GeoDA (Version 1.14).

Geospatial analysis was used to locate neighborhoods with very high-quality green spaces (90^{th} percentile) and very low-quality green spaces (10^{th} percentile). In order to determine whether observed spatial patterns or spatial clusters were statistically significant or random, Local Moran's I was used to analyze the spatial association of data

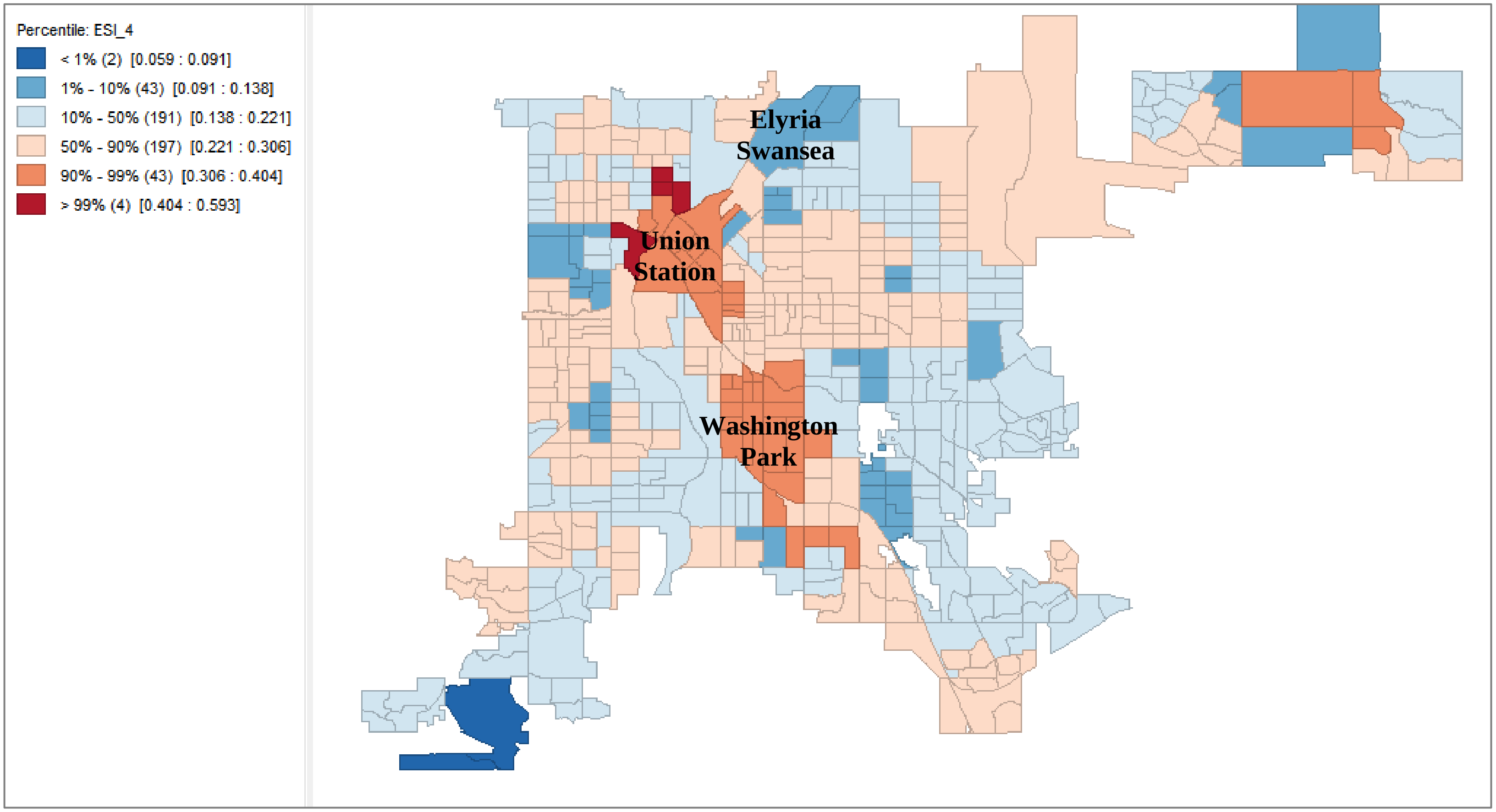


Figure 18 - Percentile map of the ecoystem servcies index scores for Denver, Colorado

clustering (Appendix E). The Local Moran cluster map and LISA map closely mirror the above percentile map (Figure 18), and all three show similar spatial patterns. Several distinct spatial clusters are revealed: one to the southwest, one in the south-central section, one surrounding the downtown area, one in the north-central section, and one in the northeast. Some of these clusters are likely due to the sampling scheme, which selected 100 out of the possible 410 green spaces in Denver. This means that not every census block group contained a green space, so the ecosystem service index scores were transferred to adjacent census blocks and blocks within a ten-minute walk, a 2500-foot radius. Regardless of this possible source of clustering bias, spatial patterns do emerge and are worth investigating. I discovered that the extremely low values in the southwest corner were due to a single small elementary school, of which there were no users on the day I surveyed its green space – thus lowering its score significantly. The cluster in the northeast appears to be an anomaly as well. It is one of the largest census block groups in Denver, and its green space is a multi-sport ballfield park where numerous games were being held on the day I visited, which raised its score significantly. Based on the percentile and cluster mapping analyses, the south-central neighborhood of Washington Park, the downtown neighborhood of Union Station, and the north-central neighborhood of Elryia-Swansea were selected for further analysis.

Table 14 - Ecosystem services index scores and components for selected Denver green spaces (n=103)

	Denver scores (mean)	**Washington Park**	**Fishback Park**	**Commons Park**	**Swansea Park**	**Globeville Landing**
Ecosystem Services Index Score	0.218	0.404	0.592	0.323	0.127	.113
Index Rank		3	1	11	92	99
Area (Acres)	27.24	157.37	2.17	17.6	10.98	8.22
Crops (Sq. Ft)	599.37	0	0	0	0	0
Trees (Number)	177.89	1316	46	374	78	18
Water (Sq. Ft)	66724	1576223	0	0	0	7228
Biodiversity	4.5	5.5	8	3.5	3	2.5
Trails (Lin. Ft)	6506	65254	1320	8492	3018	1535
Users (Number)	36.31	359	32	30	4	20
User Activities	4.39	13	3	5	1	3
Cult. Amenities	0.36	4	1	1	0	0

Case Study One: Green Privilege in Washington Park

Washington Park had the third best ecosystem service index score in Denver (Table 14). This was due to its volume of users and their diversity of activities, its abundant trees and lakes, as well as cultural amenities such as fishing ponds, historical boat house, fire station, and the location of a major environmental non-profit. The Washington Park neighborhood and surrounding environs are home to some of the highest concentrations of White population in Denver (Figure 20). Home values and incomes are also high, and this section of the city is home to established neighborhoods that have been around since the city’s inception, making it one of the most desirable neighborhoods in the city (Figure 21). The park was built in phases starting in 1899 and is based on City Beautiful principles which emphasized large geometric plazas embellished with fountains and formal landscaping. It also falls into a category of parks known as pleasure grounds, which were popular in the late 1800s and early 1900s and were created for strolling, carriage rides, picnics, rowing, and featured perennial gardens, woodlands, as well as meadows (Cranz 1982). As recreational pursuits increased in the U.S. after WWII, sports facilities such basketball and tennis were added to the park. The amenities provided by the park are likely one of the reasons it is so popular among residents and has become

Figure 19 - Washington park view of Smith Lake and the boat house, August 2019[5]

one of the most expensive neighborhoods in Denver (Figure 19). This has led some residents, though, to worry about increased density, traffic congestion, and “scrapes” – a real estate development practice which involves the purchase and demolition of an older home to make way for larger structures, oftentimes a more

[5] All images are by the author, except where noted.

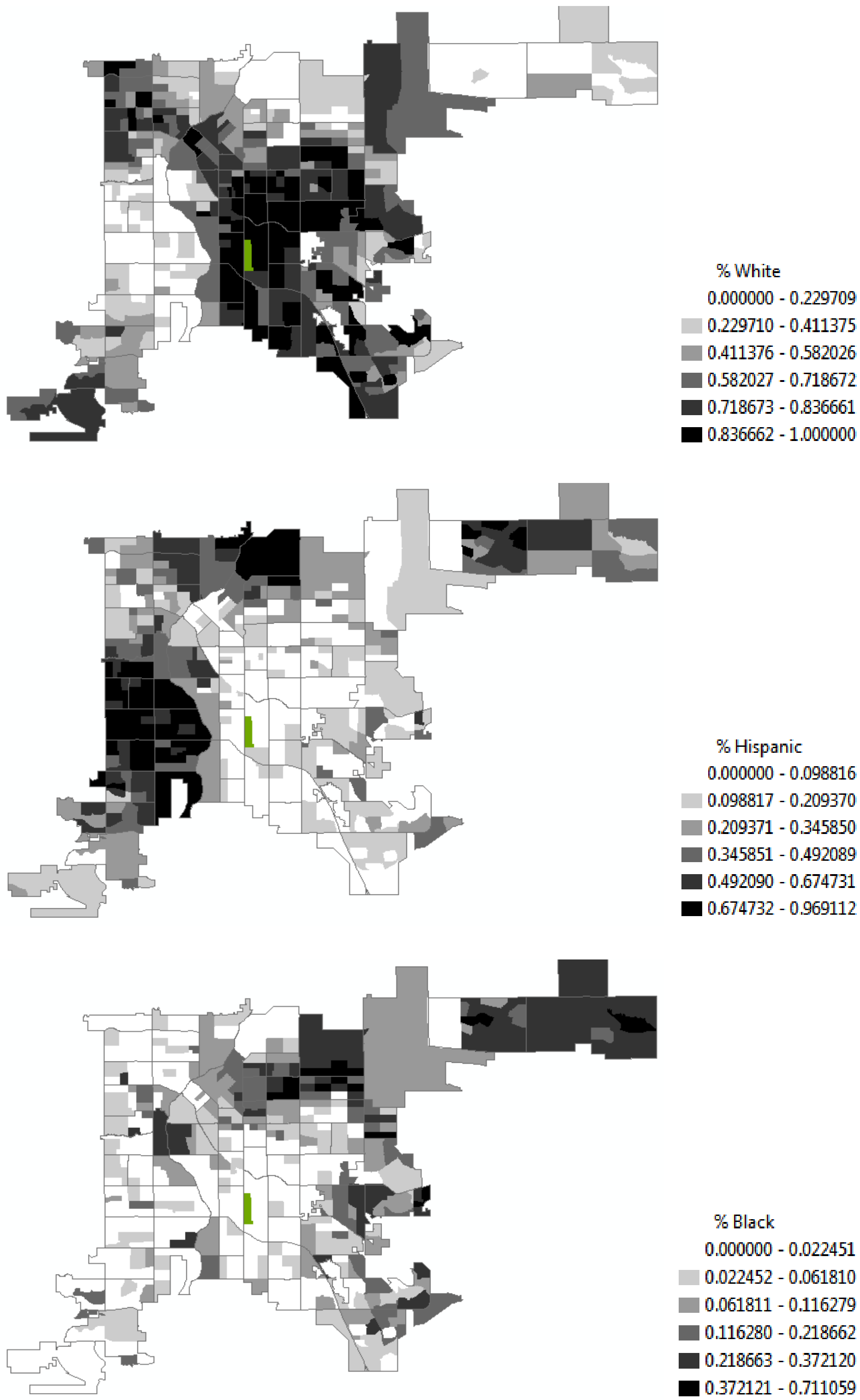


Figure 20 - Race and ethnicity patterns around Washington Park

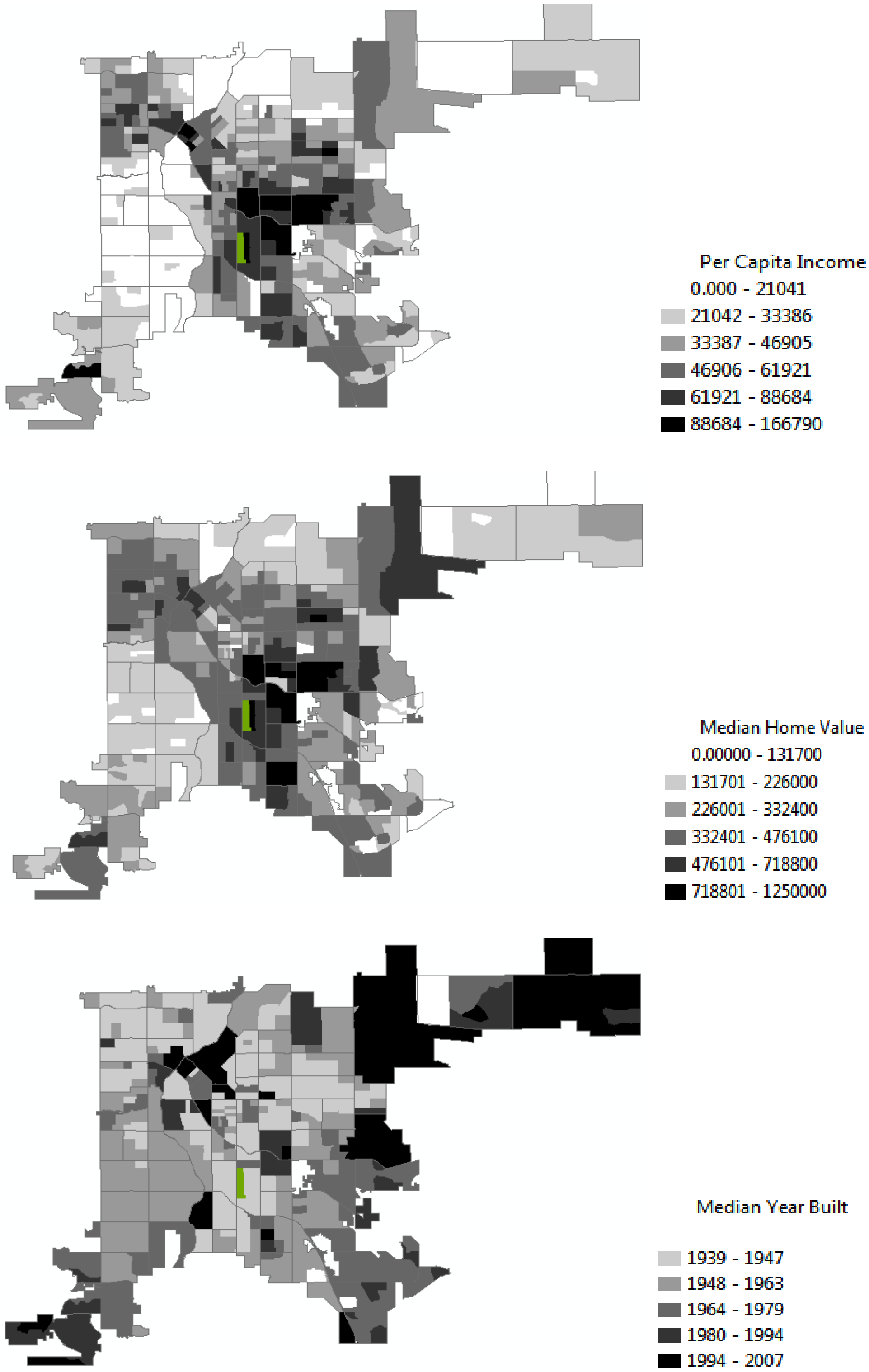


Figure 21 - Income and housing patterns around Washington Park

expensive home (Denver Post 2015). Homes along the edge of the park and in the neighborhood to the east are prone to these types of development.

The case of Washington Park appears to adhere to other research showing wealthier and whiter communities historically enjoying environmental privileges through better parks and green space amenities (Heynen, Perkins, and Roy2006; Landry and Chakroborty 2009). Whereas parks and green space in working-class and lower-income communities have historically been undermaintained, underfunded, of lower quality, and smaller in comparison (Wolch, Wilson, and Fehrenbach 2005; Boone et al. 2009). Such inequalities can often be explained by their historical and social context (Anguelovski et al. 2019).

The political economy of urban development and housing tenure often play crucial roles in unequal access to green space (Perkins, Heynen, and Wilson 2004). Although Denver has moved on from an era of formalized discriminatory policies, previous planning decisions and practices implemented in the 20th century continue to promote disparities of access to green space. According to research by Rigolon and Nemeth (2018), Denver's green space patterns originated with a funding system that was implemented in the city's early years. Funding for new parks or improvements was allocated to the wealthiest neighborhoods based on property tax revenue, such as East and South Denver. These neighborhoods also benefitted disproportionately from land donations by real estate developers trying to enhance their development's prestige, such as the Bonnie Brae neighborhood just east of Washington Park, that was built with winding streets and pocket parks designed by famed landscape architect and Denver

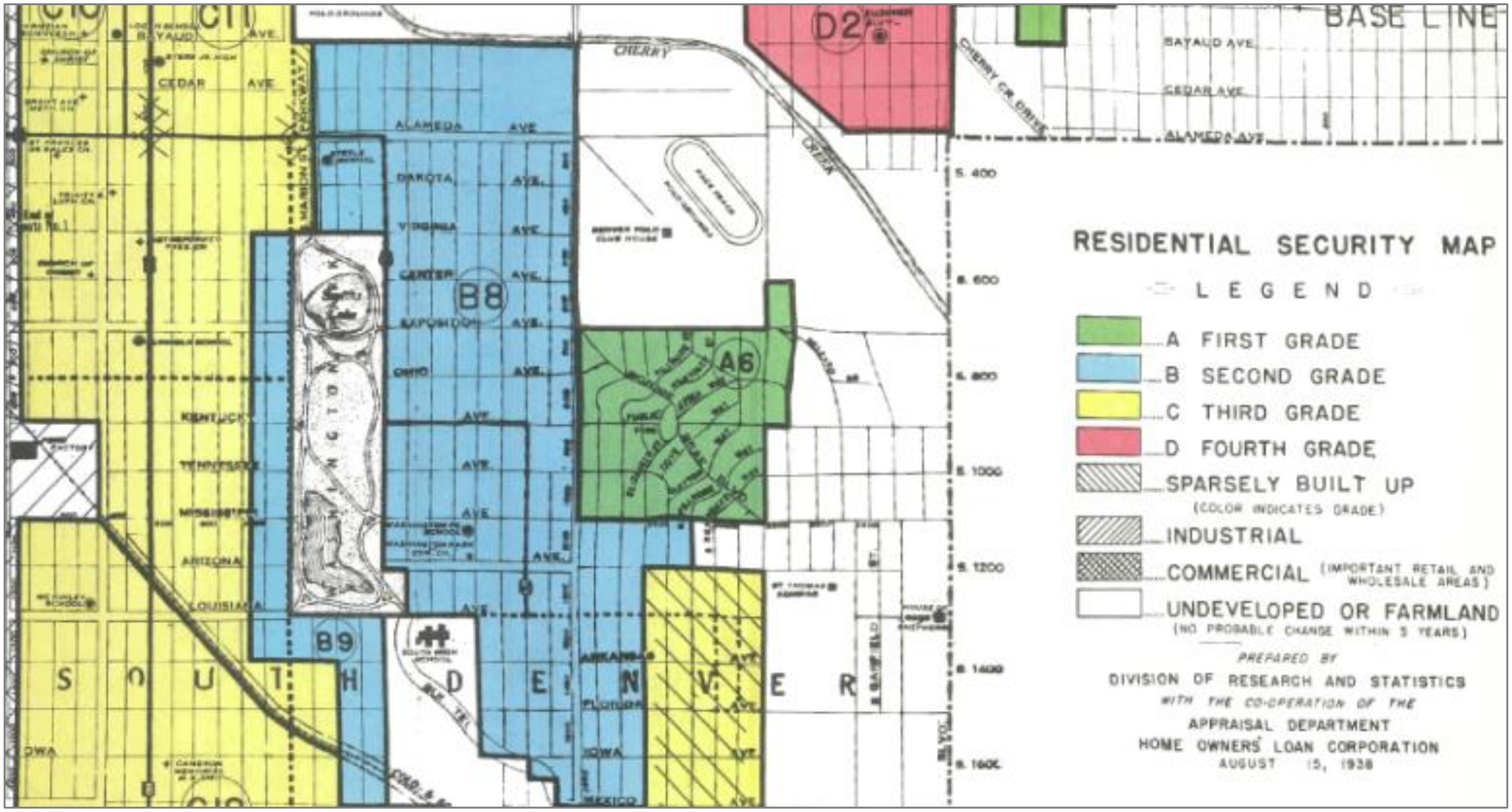


Figure 22 - Close-up of a 1938 Home Owner Loan Corporation map of the Washington Park neighborhood in Denver, Colorado (section B8 and B9 with blue shading). The A6 section with green shading is the Bonnie Brae neighborhood.

planner Saco De Boer. As with many U.S. cities, affordability and segregationist policies such as exclusionary zoning and restrictive covenants prevented lower income and ethnic minorities from buying houses in those areas. According to the Home Owner Loan Corporation, a New Deal federal agency established to refinance homes in danger of foreclosure, the areas surrounding Washington Park were listed as "B" grade neighborhoods, its second highest rating (Figure 22, Appendix F). These "redlining maps" were the product of the loan corporation's staff, along with local lenders, real estate agents, and developers who graded neighborhoods on a scale of A, B, C, or D to reflect their "mortgage security". Accompanying written assessments documented neighborhood attributes. The inscription for section B9, the section directly west of Washington Park claims that "The Park is the principal reason why this area has maintained its character." (Appendix F). This government-sponsored redlining, or in the case of A and B Denver neighborhoods, "greenlining", did not legally prevent lower-income and minority populations from buying houses and renting in these nicer areas, but it likely increased the home values, thus concentrating homeownership in prestigious neighborhoods with high quality parks.

Over time, several other social, legal, and political factors have amplified the unequal green space pattern we see today. Establishing new parks and maintaining their quality for lower-income populations became more difficult after World War II. "White flight" to Denver suburbs promoted disinvestment in the central part of Denver, lowering property tax revenues and shrinking the parks department staff and budget (Rigolon and Nemeth 2018). In 1956 a new land use ordinance was established that limited the types of construction that were allowed in established, wealthy neighborhoods. R-0 (i.e. single family) zoning prohibited rooming houses and basement apartments in neighborhoods dominated by single family homes. But residents of neighborhoods zoned R-0 used the zoning code for their own needs, giving them a legal mechanism to keep “unwanted” people out of their neighborhoods (Cole 2014). To limit Denver’s growth, Colorado adopted a constitutional amendment in 1974 that prevented city officials from annexing land from nearby counties unless a majority of that county's residents voted in favor of it. The amendment was prompted by White suburban residents' opposition to racial integration of their schools (Romero 2003). It also had the effect of preventing Denver from establishing large parks beyond the ones that already existed in affluent areas (Rigolon and Nemeth 2018).

Another phase of Denver’s history has shaped current patterns. In 2002, the Denver Planning Department came out with a new land use and transportation plan that revamped its vision for urban development, open space, transportation, and sustainability. The “Blueprint” was part of a multi-scale approach to planning that emphasized “livable communities” “new urbanism” and “smart growth” principles (City and County of Denver 2002; Godschalk 2004). Zoning was used as a tool to manage growth within its boundary, and a new “Areas of Change” and “Areas of Stability” model was established (Figure 23).

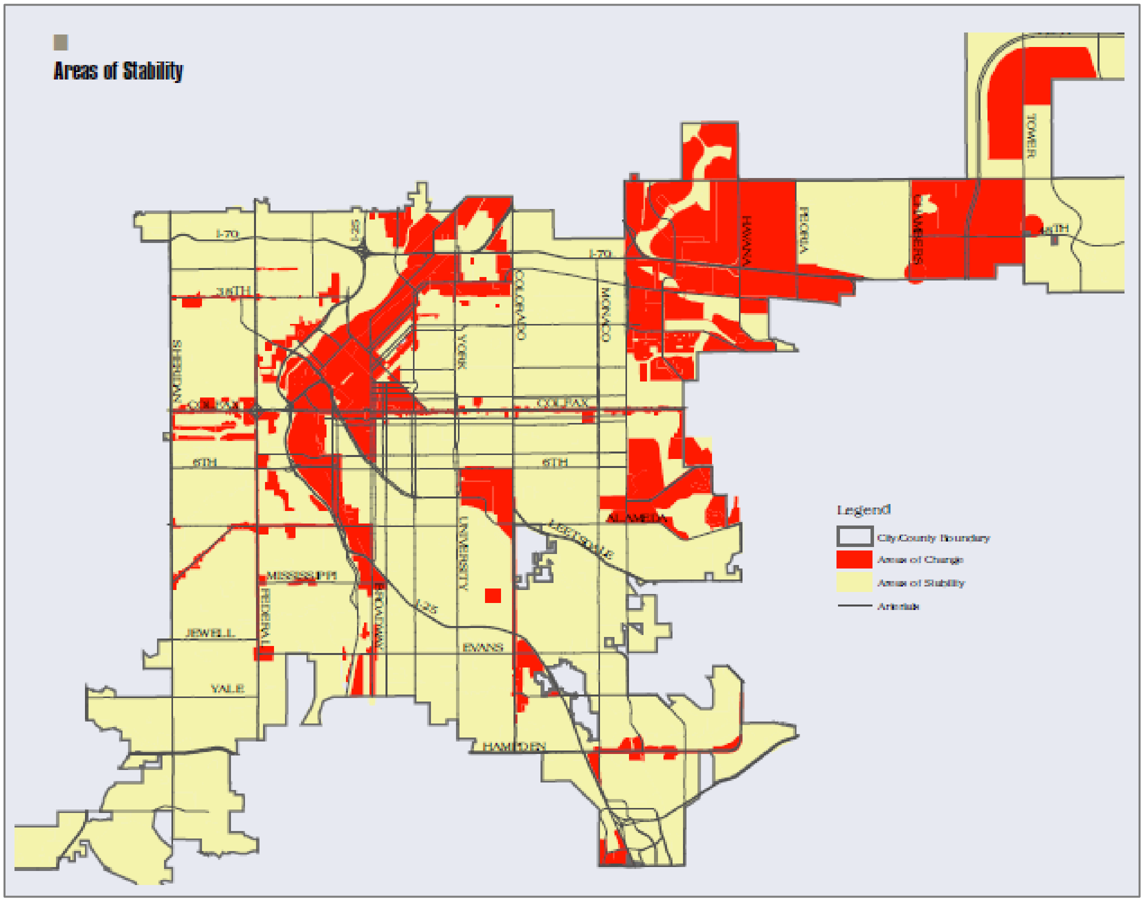


Figure 23 - Map of Areas of Change (red) and Areas of Stability (yellow) from Denver's 2002 Blueprint.

The goal was to "distribute forecasted growth to Areas of Change, where it will be most beneficial, and away from Areas of Stability, where it may have some negative consequences" (City and County of Denver 2002). While trying to "maintain the character of their neighborhoods" the Change/Stability model did allow infill development in stable neighborhoods, as long as no one called it "reinvestment":

> For example, reinvestment in the Washington Park neighborhood is not necessary to improve its character. Tools appropriate for this neighborhood seek primarily to maintain present character and to motivate modest redevelopment of selected areas, such as commercial corridors or neighborhood centers. Infrastructure, which is generally adequate, needs to be maintained (122).

A major shortcoming of the Blueprint, and the types of growth it allowed in the two decades it was active, of which Denver residents are now becoming aware, is its lack of substantive details for ensuring social equality. In fact, the term “equality” is not mentioned at all; the term “equity” is used 4 times, and only in relation to affordable housing. Urban planning during the early 2000s focused so much on the first two principles of sustainability, the environment and the economy, that equity was often sidelined (Godschalk 2004).

Washington Park clearly has many great features. It’s a great park in a great neighborhood, enjoyed by people from across Denver. However, it’s also important to understand how it fits into the greater landscape of the city, how the political economy and historical circumstances shape its current form.

Case Study Two: Devalued Demarcation in Elyria Swansea

Elyria Swansea is a Hispanic-majority neighborhood in Northeast Denver. It is home to the Denver Coliseum and Interstate 70, a viaduct overpass which bisects the area on an east-west axis. It is home to a Purina pet food facility and numerous warehouses that take advantage of its proximity to I-70. A major railroad line traverses the neighborhood from southwest to northeast. Out of the eight green spaces in the area, the two largest were selected for fieldwork.

Swansea Park and Globeville Landing Park scored in the bottom 10^{th} percentile on the ecosystem services index (Table 14). Several factors led to Swansea Park’s low score. There were only four users present, and they were doing a single activity, sitting in a car.

Both vegetation diversity transects were on turf grass, with only 3 species present. The park has 78 trees, a good amount for its size. Neighborhood access is somewhat limited because the park is flanked on two sides by a railroad yard and an alley, plus there is only one narrow entrance to the park (Figure 24). Most green spaces in Denver were designed

Figure 24 - Swansea Park in the Elyria-Swansea neighborhood of Denver, Colorado

for maximum access, with parking on all sides. Adding insult to injury, there are no sidewalks in most parts of Elyria Swansea, and none that direct pedestrians to Swansea Park. During my field visit, there was construction on the north side of the park, which may have led to further access issues and low user count. Although I visited the park during the summer at 11:30 AM on a Monday, there were no cars in the recreation center parking lot.

Globeville Landing Park's low score derives from its lack of trees and very low biodiversity (Figure 25). The twenty users observed at the park were performing three activities: biking, jogging, and playgrounding. Its trail score was also relatively very low, probably due to its linear configuration. The park lies in a conjunction of a major railroad corridor and the Platte River. The South Platte River Trail runs through the park and appears to be a major north-south bicycle byway. The park is flanked to the east by a PepsiCo bottling plant and warehouse. Since there are no residential areas surrounding the park and a large culvert flows through the middle of the park into the river, its main function appears to be green infrastructure. When I visited the green space, it was under major renovation, with a new playground going up in the northern section along with new benches, retaining walls, and landscaping going in around the park.

Figure 25 - Globeville Landing park viewed from the Washington St. bridge, November 2019

Elyria-Swansea is one of the poorest neighborhoods in Denver, with a 2016 per capita income of $14,468, far below the city average of $38,729 (Figure 26). As of 2010, the resident population of Elyria-Swansea was 83 % Hispanic, 12 % White, 4 % Black, and 1 % Native American and other ethnicities (Figure 27). Elyria Swansea appears to follow existing research which shows that lower-income populations and communities of color have less access to green space, and it is oftentimes of lower quality (Wolch, Byrne, and Newell 2014; Rigolon 2017). Such inequalities can often be explained by their economic, historical, and social context (Boone et al. 2009).

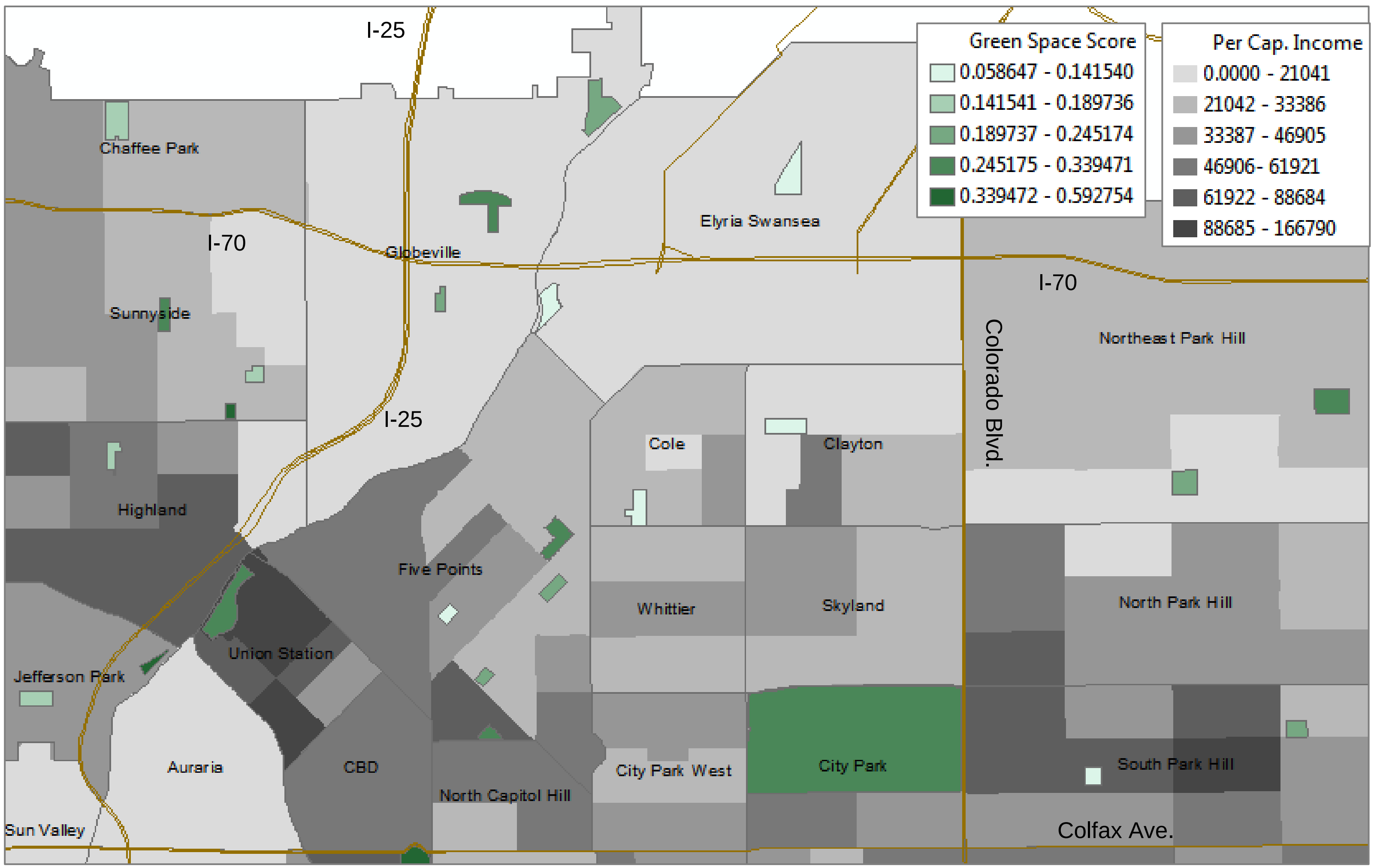


Figure 26 - Map of Northeast Denver with green space scores and per capita income by census block group

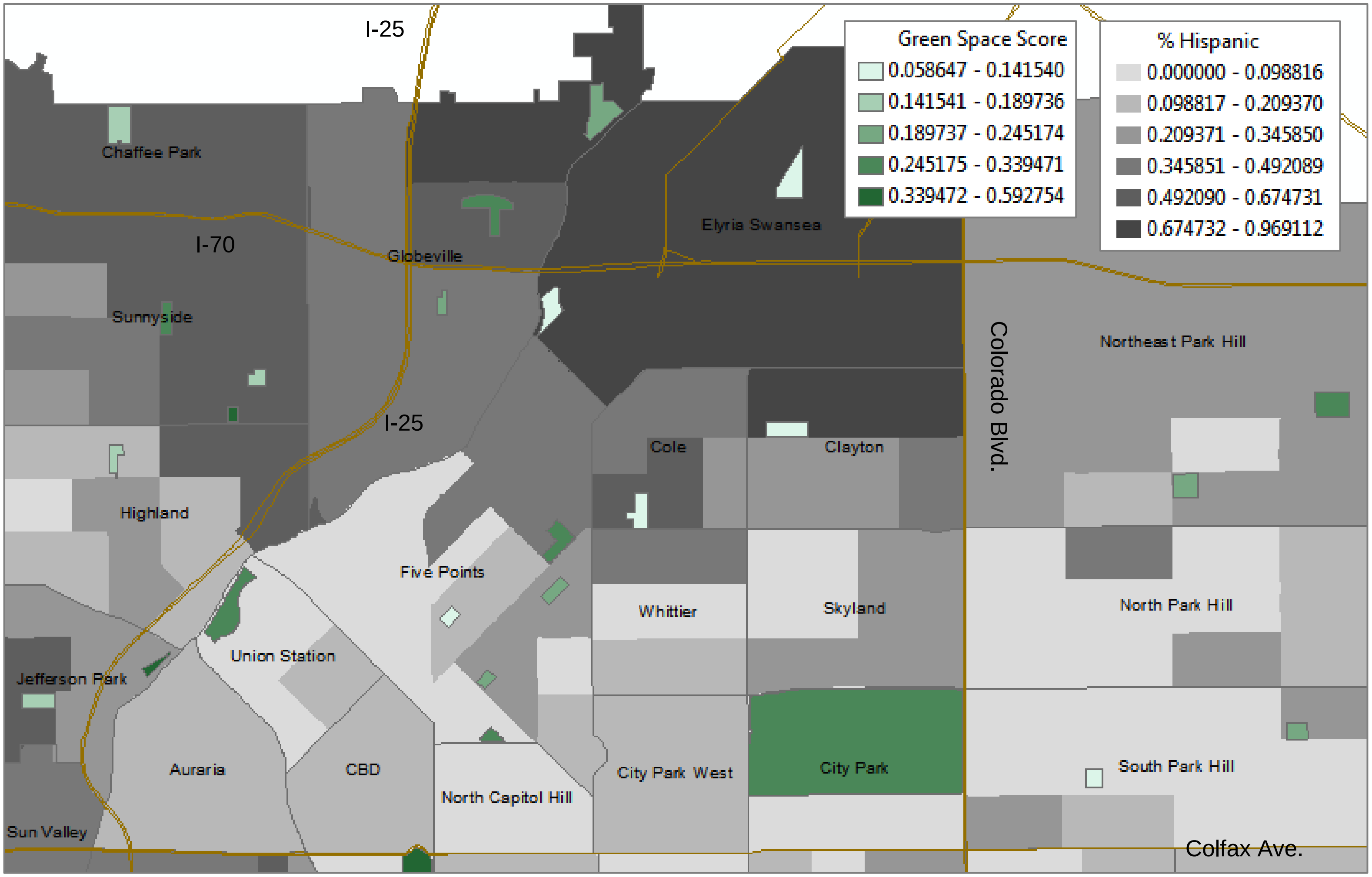


Figure 27 - Map of Northeast Denver with green space scores and % Hispanic by census block group

To understand Elyria Swansea's poor green spaces, we need to investigate economic and historical processes that have unevenly shaped the neighborhood's socio-ecological landscape. As David Harvey (1996; 2006) and urban political ecologists (Heynen, Kaika, and Swyngedouw 2006) have pointed out, urban society and the environment are linked through political-economic processes of capitalism. According to this perspective, society and environment cannot be understood separate from each other. Harvey (2006) notes: "The circulation of money and capital have to be construed as ecological variables every bit as important as the circulation of air and water". Over time, influxes of capital are invested in the landscape as seemingly innocuous features of the built environment such as buildings and infrastructure. The homes and warehouses, bridges and sewers, left over from economic booms become fixed in the urban landscape. During economic busts, as investment retreats from cities, industrial areas are particularly hard hit and become devalued and dilapidated, permanently damaged by environmental pollution and housing disinvestment (McClintock 2011).

Neighborhoods that are zoned for industrial as well as residential uses are often sites of this "demarcated devaluation". This is what the term "other side of the tracks" refers to – a demarcated area that has been devalued over time. As McClintock (2011) artfully explains:

> The contemporary cityscape is a map of previous cycles of capital accumulation and devaluation, a palimpsest of building, decay, and renewal. The walls of this prison of fixed capital are often clearly delineated by planning, policy, property taxes, and political boundaries. These buttresses and ramparts, whether or not they were crafted with intention, effectively *demarcate and quarantine devaluation* [author's italics] to prevent its impacts from bleeding over, both metaphorically and materially (94-95).

Regardless of the capital mechanisms or intention of urban planners and public officials, residents of mixed-use areas such as Elyria-Swansea often bear the brunt of neighborhood devaluation. As boom-bust cycles of capital and economic development push and pull the morphology of the city, some areas become prone to poverty, crime, and declining public health, while other areas thrive. In many cities, these same cycles can be seen in the distribution and quality of urban parks and natural amenities (Grove et al. 2018). In order to understand urban green space equity in Denver and elsewhere we need to consider the ways in which political-economic structural forces have shaped its landscape often inscribed by race and income. As environmental justice research has shown, the process of demarcated devaluation often impacts communities of color through exclusionary zoning and redlining (Maantay 2001; Boone et al. 2009), and Denver is no exception.

According to the 1938 Home Owner Loan Corporation (HOLC) map and descriptions, the Elyria Swansea is listed as a "D" grade neighborhoods, the worst rating given out in Denver. (Figure 28, Appendix F). The map illustrates the "redlining" of neighborhoods in the city and county of Denver where minority and lower income communities were excluded from receiving home loan funds because they were considered too risky for investment. The "detrimental influences" for D15 are "Unpaved streets- stench from stockyards and packing plants west of the area." The section under Inhabitants lists the neighborhood's demographics and risk factors. "Occupation: *Wage earners.* Estimated Annual Family Income: *Up to $1500*. Foreign-born families: *20% Southern European predominating*. Negro: *Few*. Infiltration of: *Wage earners*. Relief families: *About 70*. Population is: *increasing*." The Clarifying Remarks provide an overview of the area's risk:

> An area occupied entirely by industrial workers from the packing plants, stockyards to the west and other plants nearby. It has a wide range and variety of houses from cheap frames to some fair bungalows. Many are ill kept, with outside toilets. Real estate men pay little attention to the area. Demand for homes is entirely by wage earners of the low income brackets, who do not mind the stench from the stockyards districts. A fair "D".

As harsh as the remarks sound today, the language in nearby Globeville's D14 area description provides insight into the racial component and reality of lower income and minority populations to secure home loans in the U.S. prior to the Fair Housing Act of 1968 (Appendix F). A sample of the text follows.

> Description of Terrain: Level. Favorable Influences: Stores- schools- churches- adequate transportation. Detrimental Influences: Mixture of foreigners and negroes - lack of improvements. Stench from packing plants. Percentage of land improved: 35. Trend of desireability next 10-15 yrs: Down.

It's important to note that this government-sponsored redlining did not preclude lending in hazardous neighborhoods, but it likely increased the costs of borrowing to homeowners (Hillier 2003). Social and environmental inequalities have persisted in these Northeast Denver communities since the late 19th century and continue today.

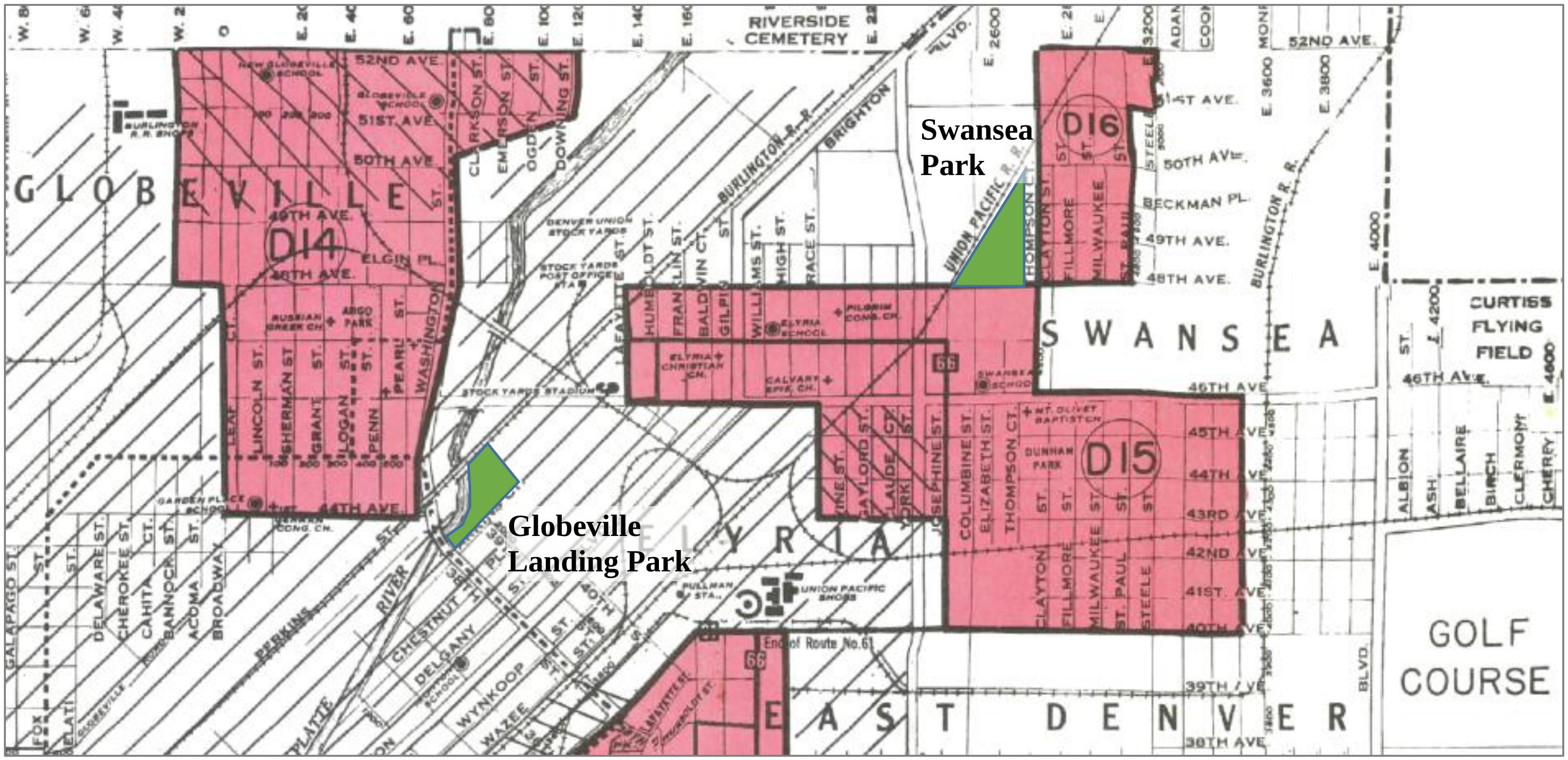


Figure 28 - Close-up of a 1938 Home Owner Loan Corporation map of the Elyria Swansea neighborhood in Denver, Colorado (section D15 and D16 with red shading). Swansea and Globeville Landing Parks are shaded in green.

Due to its proximity to the convergence of north-south and east-west rail roads, Elyria Swansea was a major smelting center for the western U.S. Starting in the 1870s, two smelting plants operated at the site for varying lengths of time, refining gold, silver, copper, lead, and zinc. As a result, heavy metals were deposited in area soils at levels that posed health risks to residents, and groundwater was also impacted (Environmental Protection Agency 2020). In 1999, the Environmental Protection Agency (EPA) listed multiple sites in Northeast Denver on the EPA National Priorities List. Elyria Swansea and the two green spaces are within a designated Superfund site know as Vasquez Blvd and I-70 (Appendix G). Sites on the National Priorities List are commonly referred to as Superfund sites because they are eligible for Superfund resources, environmental cleanup, and public participation opportunities. From 2003 to 2006, the EPA carried out a residential soils sampling and cleanup project. Most yards sampled had results below EPA's "levels of concern", and around 20 percent required further action due to elevated levels of lead and/or arsenic. The EPA removed contaminated soil from these properties, replaced the yards with clean soil, and re-landscaped.

Aside from the railroads and ubiquity of deleterious industrial and commercial activity in the area, the greatest influence on Elyria-Swansea has been Interstate 70. The roadway was built directly through both neighborhoods in the early 1960s, despite the objections of area residents and business owners (City and County of Denver 2003). The interstate was built right next to elementary schools and historic churches, and you can hear the highway din in every part of Elyria-Swansea (Figure 29). Today Elyria Swansea is predominately Hispanic, but historically it was home to eastern and southern

Europeans who worked in the nearby smelting and meat packing industries. Rending the neighborhood surely harmed the community fabric, leading to population decline and contributing to economic deterioration over the latter half of the 20th century (Goetz and Boschmann 2018).

Figure 29 - Swansea elementary school - with Interstate 70 directly adjacent to the playground

For Swansea and Globeville Landing Parks, the apparent reason for low ecosystem services scores are the lack of users and lack of biodiversity. Access and neglect appear to be major issues for both parks. This falls in line with other studies which have noted that neglect itself may not remove existing green spaces, but it can make them dangerous, unpleasant, unwelcoming, and ultimately, unused (Boone et al. 2009; McCormack et al. 2010). The simple presence of green space in a neighborhood does not mean people will automatically perceive it as an amenity or use it for recreation. In the U.S., collapsing park budgets in the 1970s, coupled with the exodus of middle-class mostly White residents to the suburbs, coincided with general declines in park maintenance and use (Low, Taplin, and Scheld 2005). Today this can be seen in many neighborhoods across Denver, especially in lower income and non-White neighborhoods. In Elyria-Swansea, traditional environmental justice concerns of neighborhood hazards interact with green space equity concerns. In recent years, Denver has tried to address these environmental justice concerns, but the outcome of these efforts is still to be determined.

In 2014, the Colorado Department of Transportation (CDOT) unveiled a plan to reconstruct a 10-mile stretch of I-70 between Brighton Boulevard and Chambers Road. It is slated to add one new express lane in each direction, remove the aging viaduct, lower the widened interstate between Brighton and Colorado boulevards, which lies right in the middle of Elyria-Swansea, and place a 4-acre park over a portion of the lowered interstate next to Swansea elementary school. Before the plan was even released, several "Ditch-the-Ditch" community groups formed to fight the proposal and advocated for the Denver section of the interstate to be dismantled and re-routed to the North. At one of the community meetings convened by CDOT, the history of the area's environmental injustices was not lost on a community member who spoke:

> Fifty and sixty years ago, when I-70, was built, this neighborhood was exploited because it was a neighborhood of immigrants from Eastern Europe," he said. "Now we have a new generation of immigrants who are being exploited because...they are powerless, they are without voice, and have no political power and have no wealth (Beaty 2016).

Although CDOT has offered a "cut-and-cover" deck to add green space to the area, pedestrian circulation could be far less, since residents will no longer be able to cross anywhere underneath the viaduct. Among the businesses the state must seize and demolish is one of the few groceries in the area, exacerbating the neighborhood's already existing status as food desert. The plan also includes the demolition of Swansea Elementary School's original playground, with a CDOT-funded relocation in the works. Post-construction, the school building will be only 125 feet from the 14-lane highway. (Crowther 2019).

Ditch-the-Ditch supporters were also critical of CDOT's proposed concession to the Elyria-Swansea neighborhood. The main community-facing project devised by CDOT is the green space highway cover. It is front and center on their project brochure and touted as "CDOT's First Highway Park" (Colorado Department of Transportation 2019). Replacing an aging viaduct with green space sounds like a good idea, especially in a neighborhood that already suffers from poor park access and park amenities. However, the 14-lane highway underneath the cap will be uncovered in spots, and elementary school students and other users will be exposed to emissions from traffic below (Figure 30). No amount of lush plantings and landscaping will override the air quality impacts to residents, who according to a 2017 report from Attom Data Solutions, already reside in the most polluted ZIP code in the United States. Any of the potential health benefits imbued to local residents from the green space would likely be negated by the health hazards from below. As the Elyria-Swansea neighborhood gets ready for its newest green space in decades, residents in other parts of Denver have recently seen new or restored parks, playgrounds, and greenways in their neighborhoods.

Figure 30 - Artist rendering of the proposed green space cap over a refurbished I-70 in the Elyria-Swansea neighborhood of Denver (CDOT 2019)

Case Study Three: Green Gentrification in Union Station

The Union Station neighborhood in Denver has undergone an enormous transformation in the last few decades. It began with a renewed flourishing of Lower

Downtown in the mid-1960s, was propelled by the creation of a major walking mall in 1982 and the construction of a major league sports ballfield in 1995. It is now in its final stages with the refurbishment of Union Station, which has become the de facto public transportation hub of the region.

Two green spaces in the Union Station area were selected as part of the sampling pool for the ecosystem services index. Fishback Park and Commons Park scored in the 90th percentile, with Fishback having the highest overall score of .592 (Table 14). Several factors led to these high scores. Fishback Park, at just over 2 acres, was one of the smallest green spaces that was sampled. Despite its size, it had 46 trees, a relatively high biodiversity count (8 vegetation species), and a relatively high user count. Its location next to the Platte River on one side and natural landscape plantings in the center of the park led to its high biodiversity scores. Its three main user activities were all highly kinetic such as walking, jogging, and biking, which meant that a high volume of users was able to move through the green space quickly. Fishback Park is adjacent to a major aquarium and has its own dedicated parking area, which means there are multiple access points for pedestrians (Figure 31).

Fishback Park – looking south

Fishback Park – looking north

Commons Park

Commons Park – looking north

Figure 31 - Commons Park and Fishback Park in the downtown Denver area

Commons Park is across the Platte River, downstream and closer to downtown and Union Station itself. Due to its riverfront location and new street tree plantings, it has the second highest number of trees per acre out of all selected green spaces. It has a higher than average number of trails, and although its user count was relatively low, they were performing a highly diverse number of activities such as biking, dog walking, scootering, walking, picnicking, and sleeping. In order to gauge the socioeconomic and demographic profile of the area, I mapped and analyzed the Union Station neighborhood and surrounding census block groups. Additional mapping products on sociodemographic changes in Denver from 2000 to 2016 are available in Appendix H. The transformation of the lower downtown area as noted above led to a dramatic population boom. From 2000 to 2016, the population in Union Station and neighborhoods within a 10-minute walk of the two green spaces – Highlands, Ball Park (which is part of the Five Points census tract), Auraria, and Jefferson Park – grew by 10,000 residents. This area has some of the highest population growth in the city (Figure 32) and its newest homes and apartments, which are mainly expensive, mixed-use, high-density residential units (Figures 33 and 34). Many of the new residential buildings are luxury apartments catering to the influx of millennials, back-to-the-city boomers, and young families (Goetz and Boschmann 2018). As large-scale capital investment and urban redevelopment focuses on the Union Station area, local and adjacent neighborhoods feel its impact as their local real estate markets heat up. The downtown area has some of the highest home value growth rates in the city, which puts financial pressure on existing residents, forcing many families that have been there for generations to move.

Gentrification can be defined as a significant change in an area's social-demographic-economic structure, physical environment, or overall neighborhood culture which leads to the displacement of existing residents and businesses with more affluent residents and up-

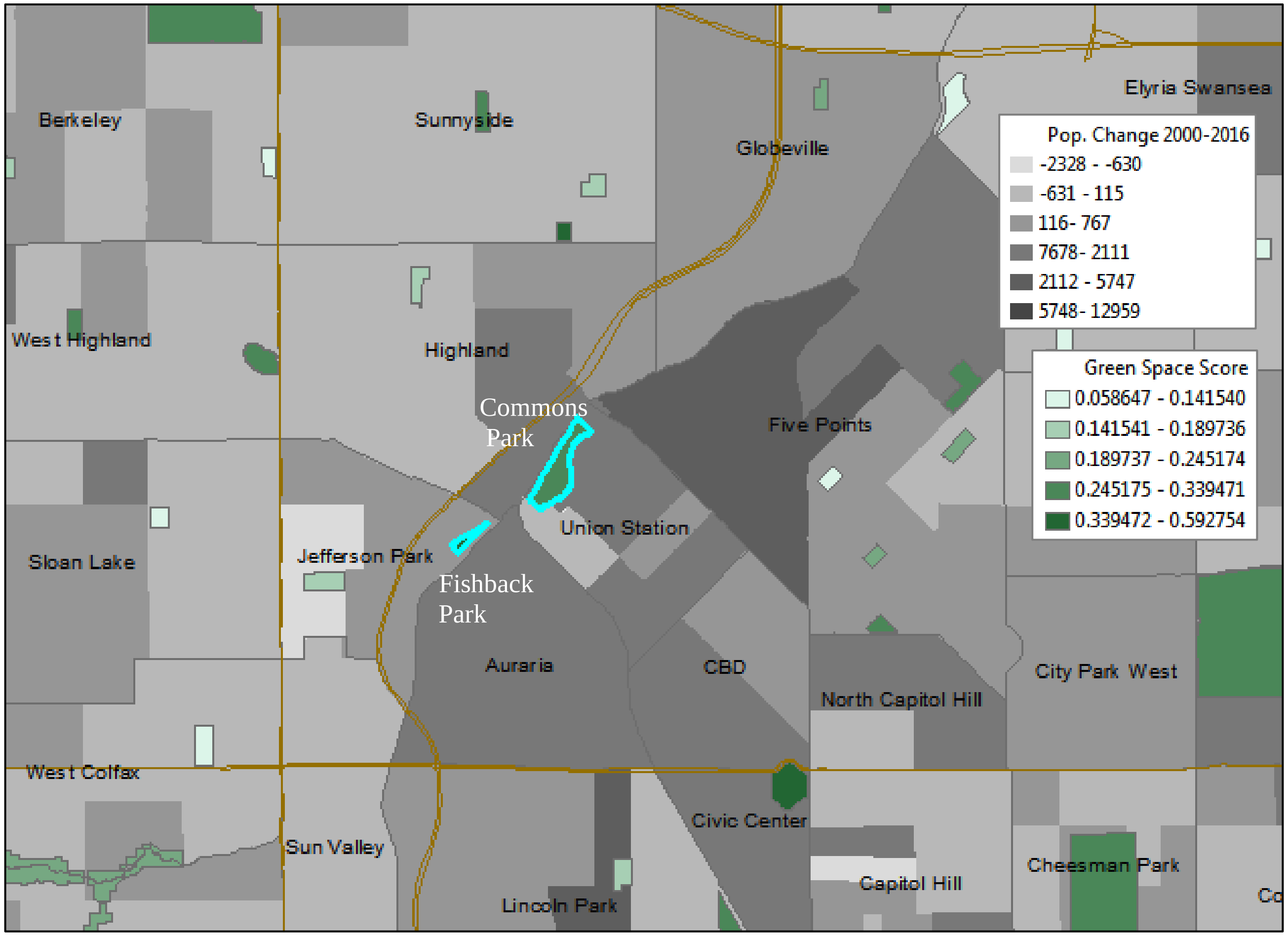


Figure 32 - Map of Union Station and surrounding neighborhoods with green space scores and 2000 - 2016 population change of census block groups; Fishback Park and Commons Park are highlighted in blue.

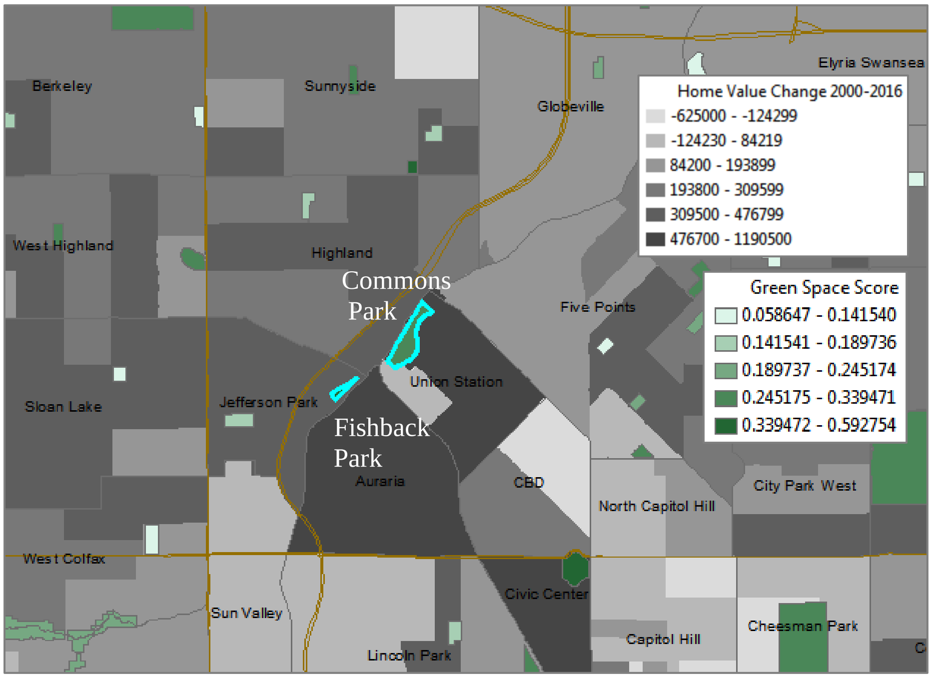


Figure 33 - Map of Union Station and surrounding neighborhoods with green space scores and 2000 - 2016 home value change of census block groups; Fishback Park and Commons Park are highlighted in blue

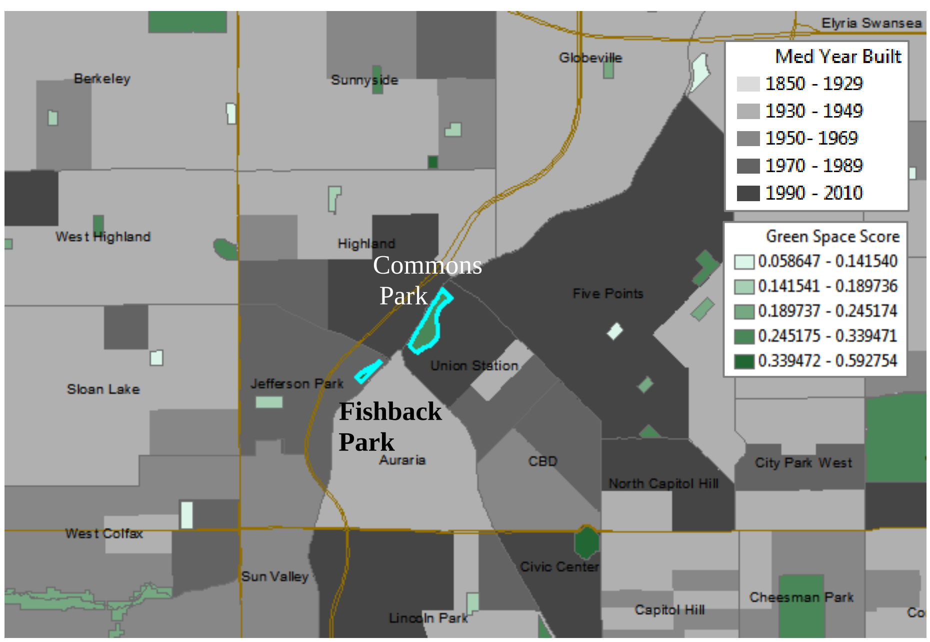


Figure 34 - Map of Union Station and surrounding neighborhoods with green space scores and the meadian year of home built by census block groups; Fishback Park and Commons Park are highlighted in blue

scale businesses. In the U.S., displaced residents are usually lower-income populations or people of color who are replaced by higher-income residents and more affluent non-Hispanic Whites. The population and demographic shifts in the Union Station area suggest a classic gentrification dynamic, which may be getting amplified by its high-quality parks and newly refurbished green spaces. Urban geographers, urban political ecologists, and urban planning scholars have recently demonstrated that the creation or renovation of urban green space sometimes creates enclaves of environmental privilege, causing more harm than good (Curran and Hamilton 2012; Anguelovski 2016; Anguelovski et al. 2018). Greening projects often take the form of parks, greenways, green infrastructure or community gardens, and are often articulated by private investors, public officials and urban planners as sustainability projects (Anguelovski et al. 2019). Although urban greening and sustainable development are commendable approaches for improving green space, mitigating contamination, and even combating climate change, they may have unintended consequences which result in adverse social and economic impacts to existing residents.

Green, environmental, or ecological gentrification is defined as “The implementation of an environmental planning agenda related to public green spaces that leads to the exclusion of the most economically vulnerable human population while espousing an environmental ethic” (Dooling 2009). New York City’s highline park is often cited as an example of green gentrification. The dilapidated raised subway line which runs through Manhattan’s west side was rescued by local activists and refurbished as an aerial greenway in the late 2000s. It opened to accolades from urban planners and landscape architects and has become one of the most popular destinations in the city, attracting millions of visitors a year. Originally hailed as an innovative greening project replete with native plantings and historic railroad elements, the park quickly became a magnet for boutique hotels and luxury residential towers leading to disaffection from residents whose criticisms were often met with deaf ears (Loughran 2014). Like other urban sustainability programs, such urban green space strategies may have paradoxical outcomes. If they are successful, they may ultimately exclude residents who need them the most (Wolch, Byrne, and Newell 2014).

Urban green residential developments and green space improvements are often couched in the constructive, apolitical tone of sustainability. This falls in line with frequently used discourse of sustainability and economic development planning projects which leave little room for dissent and locals being "wiped out by the greenwave" (Checker 2011). Land development transactions, activated by real estate actors and approved by government officials, are part of what Molotch (1976) called the "growth machine" which invests capital into neighborhoods. Taking this analysis one scale higher, redevelopment is now often simply a cog in the machinery of global capital, detached from the needs of local communities (Harvey 1989). "Green growth machine" projects are no exception; they are linked to broader structural changes in society such as globalization, neoliberalism, and the "sustainability fix" needed to keep capital going (While, Jonas, and Gibbs 2004; While, Jonas, and Gibbs, 2010). Ironically, once these "environmentally-friendly" urban projects are complete, the properties become obstacles to capital accumulation, leading to resource-intensive redevelopment cycles which are “far shorter than would be environmentally or socially optimal” (Agyeman 2013). There is growing concern that sustainability, as it has matured and despite its merits, has simply become part of the machinery of urban development.

Urban greening projects tend to focus on providing spaces of consumption, recreation and leisure for highly educated, higher-income workers in the creative economy (Questal 2009). They entice would-be residents with images of green oases and hubs for sustainable planning technologies like walkability, public transport, and proximity to farmers markets and greenways (Wachsmuth, Cohen, and Angelo 2016). City branding is an important component to many redevelopment projects (Gulsrud, Gooding, and van Den Bosch 2013). City rebirth and re-placemaking have been documented across the U.S. One example is Portland’s industrial waterfront transformation that follows a familiar model of blighted areas making way for condos, restaurants, offices, and galleries. Ecological restoration, urban livability, and sustainability are part of the “urban imaginary” of developers, planners, and residents (Hagerman 2007). Many of the new residential buildings in Downtown Denver follow this logic, with buildings named after local green spaces and Union Station: The Confluence, Riverfront Green, the Station at Riverfront Park, Balfour Riverfront Park, Union Denver, Platform at Union Station, and Highland Bridge Lofts (Figure 35).

Figure 35 - Platte river refurbishment project in downtown Denver, 2016; “Flagship” REI store on the left and construction of The Confluence (also the name of the green space below) apartment building on the right

Sustainability is often defined by its three Es - environment, economy, and equity. The primary foci of Denver’s sustainability efforts since their inception have been on the first two Es. Mayor Hickenlooper was an early signer of the U.S. Conference of Mayor’s Climate Change Agreement in 2005, and sustainability is well-represented in Denver’s comprehensive plan (Portney 2009). However, it’s focus on energy efficiency, greenhouse gas emission, and natural resource conservation has led it to ignore the third E – equity. As of late, Denver’s sustainability programs have been rebranded to address current environmental priorities and lingo. Their updated website (City and County of Denver 2020) is titled “Climate Action, Sustainability, and Resiliency”, and there is still very little mention of equity. Denver is not alone; most U.S. cities and municipalities have sustainability programs, but only 26% of them prioritize social equity (Liao, Warner, and Homsey 2019). Even when they do highlight equity, due to the complexity of contemporary society, there is no guarantee of positive outcomes. Although sustainability has the potential to be truly transformative, its initiatives are often implemented through “strategies of affirmation” (Fraser 2009). Even if these strategies address equity, they don’t necessarily challenge the fundamental epistemic, social, and urban spatial structures that produce injustices in the first place. Sustainability must be transformative, not just affirmative (Fraser 2009; Castan-Broto and Westman 2017).

Within sustainability programs, urban greening and the creation of green space checks all the boxes; it helps improve public health, the environment, and the housing market. These are admirable qualities, but ultimately the alliance between urban redevelopment and greening initiatives appear to create a green space paradox. A paradox brought to life by city sustainability programs, international investment, and wealthy residents to produce and capture a “green rent gap” from the social, environmental, and health benefits of new green space (Anguelovski et al 2019). Denver appears to be actively cultivating green space luxury for the privileged and creative classes that are flocking to its hip and sustainable downtown. But if lower-income and non-White residents can’t afford the price of admission, they may end up being excluded from the very green spaces that are being created and restored.

Although green gentrification is on the rise across the U.S. (Rigolon and Nemeth 2020), it is starting to be contested and potential sustainability solutions to its scope and impact are being proposed (Anguelovski et al. 2019). One of the most well-known examples of anti-green gentrification theories and community interventions has been the “just green enough” approach (Curran and Hamilton 2012; Wolch et al. 2014). It employs a collaborative strategy whereby residents, planners, and land developers work together before redevelopment projects get underway to avoid the “parks, cafes, and riverwalk” model of a green city. Using this approach in Greenpoint, Brooklyn, participants were able to clean up existing contaminated sites and create new green spaces near existing working-class neighborhoods without inciting speculative land development. With respect to urban sustainability initiatives, cities need to do improve their capacity to provide what’s called procedural justice, i.e. formalized approaches to citizen engagement. This could take the form of sustainability-oriented citizen task forces and cross-agency collaborative teams with links to economic development actors. An engaged group of public officials, community members, and non-profits may be able to mitigate the conflicts between the three Es and help cities and neighborhoods pursue a more balanced agenda for local sustainability (Liao, Warner, and Homsy 2019).

On a more structural level, there are a number of actions local governments can take to stabilize communities and prevent rapid gentrification: introduce affordability protections for businesses and residents; institute anti-gentrification rent controls; accommodate zoning ordinances that prevent new developments which are stylistically or culturally out of neighborhood context; encourage appropriate restorations and rehabilitations of older housing stock, and provide financial incentives for homeowners and landlords to do so; create new mixed-use zones for human-scaled buildings; and encourage smaller land development projects scattered throughout the city, rather than large green infrastructure projects. As mentioned above, sustainability needs to be less affirmative, less a “yes man” to capital and more transformative. If equity principles were routinized into its operations, it could be an effective tool to navigate cities away from green gentrification.

Discussion and Conclusion

These three case studies together build up a narrative of contemporary challenges and opportunities for public urban green space in Denver, Colorado. In the Washington Park case study, I drew out important historical details on how its residents have been the recipients of early land donations, favorable zoning and housing tenure laws, constitutional amendments, and finally 21st century planning schemes that enshrined its stable character for years to come. In the case of Elyria-Swansea, I outlined its history of environmental justice concerns, explained how flows and ebbs of capital created its demarcated devaluation and the impact this had on the neighborhood’s social fabric, especially considering its history of redlining, pollution, and the ill effects of regional transportation planning decisions. The green space equity concerns of this neighborhood are dire, as its newest park is being built on top of a 14-lane highway, which may pose more dangers to the community’s health than any health and ecosystem services that grass and trees can supply. In the case of the Union Station neighborhood, the paradoxes of urban greening programs were explored through the lens of green gentrification. This new way of looking at how urban politics, sustainability programs, and developers form a new growth machine, is of concern, considering existing residents are wiped away by the green wave. The framework of sustainability can be a powerful tool for good, if the third E – equity – isn’t left holding the bag.

As mentioned earlier, Denver has moved on from an era of formalized discriminatory policies. Yet previous planning decisions and practices implemented in the 20^{th} century continue to promote a green space divide in Denver. Unfortunately, lower-income populations and communities of color are used to this; they've been excluded from large and high-quality green spaces for decades. They're also starting to see the neighborhoods their families have been in for years rebranded as "sustainable", "livable", and "green" at their expense. This green space paradox sets up a further unfortunate dynamic, where even the best environmental justice intentions of industrial remediation and the creation of new green space, as in the case of Elyria Swansea may be a zero-sum game, with every green space gain equal to a green space loss for others. Thankfully, some of these negative outcomes are not set in stone, and with the right tools, they can be led in the right direction.

Chapter Six: Bridging the Green Divide: Findings, Solutions, and Conclusion

Findings

Several key findings came out of this research. Although green space distribution in the Denver Metropolitan area adheres to much of the research on green space inequity, with lower-income and communities of color having less access, it is different in several ways.

General Findings

Chapter Three examined the distribution of green space by the access measures of proximity and acreage. Following national and global trends (Rigolon 2016), Lakewood's Hispanic and less educated populations have relatively little access to green space for both acreage and proximity. For Denver, non-White and lower income populations have slightly better access to green space than White and higher income populations, which is counter to most green space equity studies, but does fall in line with cities such as Baltimore, whose Black populations live in highly urbanized areas near downtown with numerous small parks (Boone et al. 2009). In this sense, the distribution of Denver's green spaces appears to act as a mitigator of race and income inequality, although more research is needed in order to gauge the impact that urban growth patterns and gentrification may be having on this outcome. For Aurora, its White population has much better access to green space than its Hispanic, Black, and Asian populations. This was a surprising result since Aurora is a minority-majority city, but like Denver, many of its communities of color, especially Asians tend to cluster in smaller census blocks closer to downtown Denver with relatively small green spaces. This chapter quantified urban green space by proximity and acreage, but didn't tackle its quality, which is a gap in the green space equity research.

Chapter four examined the quality of urban green space, as measured by its ecosystem services. A main objective of this chapter was to determine if green space quality in the Denver Metropolitan area follows the same distributional logic as its green space quantity. Using a unique ecosystem services index based on field survey and GIS features as a multidimensional proxy for quality, I found that correlations between green space quality and socio-economic variables vary widely across the study area. Lakewood and Aurora appear to have the least amount of disparity, and one of the most striking patterns is the positive relationship between the ecosystem service index scores and White populations in Denver. *Lakewood's* ecosystem scores are the lowest, which means that its green spaces provide the least amount of benefits to users. For Lakewood, all results were rather weak across the board, showing only minor statistical relationships among green space quality and socio-demographic variables. Nevertheless, an interesting pattern emerged: the green spaces in predominately White neighborhoods with higher home values provide less ecosystem services than Hispanic and Black neighborhoods. *Denver's* census block groups have the highest ecosystem service scores in the study area, and the results showed statistically significant racial, gender, education, and income disparities. A surprising but noteworthy result is that neighborhoods with a high concentration of females have statistically less access to high quality green spaces than males. *Aurora* had just a few statistically significant results. There are very weak negative correlations between Hispanic and Native American populations and high levels of green space ecosystem services, while there are weak positive correlations for Black and Asian populations. The most significant finding here is that Asian populations appear to live in neighborhoods that have the highest quality green spaces in all of Aurora, which is interesting considering the previous chapter's results that showed its Asian populations had less access. The chapter was rounded out with a discussion on reasons for the Area's green space patterns, including green space feedback loops and the nature of urban landscapes.

Chapter Five analyzed three distinct neighborhoods in the Denver Metropolitan area based on the green space ecosystem service scores from the previous chapter. The first section examined Washington Park, with its high ecosystem service scores and disproportionately White and higher-income populations. I outlined factors that led to the neighborhood's green privilege, such as historical details on how its residents have been the recipients of early land donations, favorable zoning and housing tenure laws, constitutional amendments, and finally 21st century planning schemes that protected its stable character. The second section examined Elyria-Swansea with its very low ecosystem services scores and disproportionately Hispanic and lower-income populations. I outlined its history of environmental justice concerns, its history of redlining, pollution, and the equally harmful social effects of race-based regional transportation planning decisions. The analysis ends with a short history of its newest environmental justice struggle – the expansion and lowering of Interstate-70. This project is slated to create Denver's newest green space, although since it will be placed directly over the 14-lane highway section, may end up doing more harm than good. The third section examined two of the highest scoring parks Denver, and its surrounding Union Station neighborhood. The concept of green gentrification was applied to this park-rich area, and linkages between urban greening projects, sustainability programs, and the green growth machine were considered. The framework of sustainability can be a powerful tool for good, but only if its third E, equity, takes a larger role going forward.

Ecosystem Services Approach

Besides the specific findings of each chapter, there some general findings on ecosystem services that I would like to point out. I believe this project proved that the ecosystem services framework can be a very useful tool for human-environmental research, an integrative way to measure both ecological quality and human benefits. This is especially true for green space equity research. Most existing literature uses crude measures of quality such as park facilities, levels of maintenance, crime, and safety (Rigolon 2016). These one-dimensional properties do not and cannot capture the full variety of ecological affects and human-cultural responses to green space. Even though parks and ball fields seemingly convey very few ecological benefits, they can be not only rich in wildlife and species essential to biodiversity, but the sites where human lives unfold, where families hold birthday parties, where parents cheer as their sons and daughters kick their first goal. At the same time, the wildest green spaces which exhibit the most ecosystem properties appear to offer very few cultural services to people. Yet the few who do appreciate them the most, have sometimes had life-altering, spiritual experiences in them and would protect them with their lives. The ecosystem services concept, although not perfect, does a good job of capturing a wide variety of ecological ephemera and cultural benefits, especially when used at the landscape or neighborhood scale of green space. Indeed, if operationalized within urban and green space planning, it could help us navigate through the various tradeoffs that make siting and refurbishing green space so challenging. In many ways, the institutions that we set up for ourselves are ultimately what holds us back. Along these lines, I believe that urban ecosystem services need to be researched more and taught about in our K-12 schools, so that people can appreciate them, and in turn defend them. Urban green space governance is also important, and there should be sustained research into its social and cultural context (Kremer et al. 2014; Haase, Frantzeskaki, and Elmqvist 2014). See Appendix I for my thoughts on ecosystem services and institutions.

Solutions

Chapters Three and Four of this dissertation attempted to capture the urban green space disparities exhibited in the Denver Metropolitan Area. They primarily dealt with one pillar of environmental justice – distributive justice. Over its short life span, the green space equity field has been very good at documenting distributional patterns but has not yet done a good job of documenting the procedural and recognition challenges of green space.

The environmental justice literature has a rich theoretical history emanating from the political philosophy and social ethics of John Rawls. His classic book *Theory of Justice* prescribes a way of structuring societies to maximize personal liberty, while only allowing social or economic inequalities if the worst off in society would be better off than if resources were equally distributed. Additionally, for those that suffer under social or economic inequality, they should have equal access to offices and positions of power within society. His ideas were brought into environmental justice research by Dobson (1998), Young (1990), and Schlosberg (2007) who applied Rawls principles of justice to environmental problems that disproportionately affected socially and economically disadvantaged people. While Rawls' focus was on distributional justice, Young's feminist and postmodernist outlook attempted to displace the Rawlsian paradigm that focused on distribution for one that considered the social and cultural contexts of injustice. According to Young, the social and institutional factors that lead to distributive injustice are in fact intertwined with how members of society that face economic inequality lack social recognition and representation, which leads to exclusion from political process and decision-making. Accordingly, recognition and representation are crucial human needs, and if not fulfilled, will lead to inequitable outcomes such as the unjust distribution of goods and services (Nesbitt et al. 2018).

The green space equity research community has primarily focused on the distributional aspects of environmental justice. The spatial logic of green space distribution is relatively easy to map and analyze, but as Young suggests, this is only one piece of the justice puzzle. In order to move green space equity research forward, the social and institutional contexts of recognition and representation need to be addressed (Boone et al. 2018). This section draws heavily from Nesbitt et al (2018), who proposed a new equity framework for analyzing urban forestry practices based on three dimensions of environmental justice theory: distribution, recognition, and procedure. I have translated and expanded a few of its salient arguments here into the context of urban green space.

Distribution

Distribution is clearly a principal dimension of urban green space equity, based on the environmental justice, ecosystem services, and park access literature discussed above. The spatial distribution of green space is increasingly important to municipal policies and practices, especially since its location in relation to urban residents' homes and places of work influences whether, how, and when people have opportunities to access it. Many ecosystem services associated with urban green space affect residents directly – such as air quality improvements (Nowak, Crane, and Stevens 2006; Pataki et al. 2011), improved microclimates (Lafortezza et al., 2009; Escobedo, Kroeger, and Wagner 2011), psychological health benefits (Ulrich et al. 1991; Kondo et al. 2020), and physical health benefits (Thompson et al. 2012) – and may only be experienced near green space. For example, residents may have physical responses to improved air quality while walking in a densely forested park or may feel reduced stress and higher levels of wellbeing when exercising outdoors than in a gym.

Recognition

Recognition in decision making is another key dimension of urban green space equity. The term implies both access to and power within formal and informal decision-making processes. Recognition in green space policymaking may determine residents' ability to influence its management for their benefit, the benefit of society, and even benefits to the environment (Nesbitt et al. 2018). For instance, site management and community input at informal green spaces and community gardens have been shown to greatly enhance community ties and ecosystem service productivity in crops and species richness (Dennis and James 2016). The ability to influence green space decisions may thus equate to generating positive outcomes such as better amenities, conditions, and ultimately allocating, re-configuring, and designing new or improved green spaces. In addition, residents may derive benefits through the process of participating and having power in decision-making processes, such as increased community cohesion and sense of place (Buijs et al., 2016; Fisher, Svendsen, and Connolly 2015). Recognition in decision making is therefore a key dimension of urban green space equity.

Representation and Procedure

Representation, i.e. inclusion, is a fundamental sub-dimension of recognition and urban green space equity. An actor must have a seat at the table and have power within the decision-making process in order to influence the process and its outcomes (Schlosberg 2007; Nesbitt et al. 2018). Once they are present, the process itself must be fair and respect the voices of all participants. This ensures procedural equity and recognition for all participants, rather than perpetuating inequity by excluding certain voices in the process. Numerous examples of how the lack of procedural justice for African American communities in Baltimore have impacted the city's urban park system, and their relationship to it (Boone, 2002; Boone et al., 2009; Boone et al. 2018). Procedure is an important sub-dimension in that it determines who makes decisions on the allocation and management of green space. Encouraging a diversity of voices and perspectives on issues pertaining to green space can help ensure that they are distributed equitably. This will in turn ensure that their ecosystem services, especially cultural services such as social relations and sense of place, are as well (Daniel et al. 2012; Anguelovski 2014; Nesbitt et al. 2018).

Achieving representational and procedural equity is a complex, challenging task, particularly in culturally diverse urban settings. Even when formal decision making has been designed to promote both representational and procedural equity – as is the case of Denver's Parks and Recreation department which regularly holds community meetings – applying those policies in practice can be challenging. First, green space decision making involves multiple actors and coalitions. Cities often work with external partners, other governmental agencies, non-governmental organizations, and private companies to conduct green space design and management. Most cities have formal and informal channels through which public and private actors may influence urban green space decisions (Trust for Public Lands 2018; Nesbitt et al. 2018). Second, as urban political ecology research has shown, uneven power dynamics may undermine existing and future equity policies, especially because of the complex ways in which gender, race, and class interact and intersect in urban environments (Heynen, Perkins, and Roy 2006; Doshi, 2017). For example, equity policies and procedures, especially of formal institutions like urban planning departments, have evolved with and exist within a political-economic context that has historically disregarded residents' concerns based on their social status (Gunder 2006). Third, for participatory decision-making to be effective and inclusive, it takes time, which many formal urban green space actors such as Parks and Recreation department heads and mayors do not believe they have (Newig and Fritsch, 2009). Finally, formal decision making is only one piece of the complicated reality of governing urban green space. The landscape context of green space is often overlooked, as it exists within a matrix of public and private land uses and land cover types. This landscape mosaic is mirrored in the social landscape as a heterogenous array of people, institutions, and spatial practices (Buijs et al. 2016; Boone et al. 2018). The relative decision-making power of actors involved in urban green space thus influences the outcomes of those decisions, which may result in green space being preferentially distributed to more powerful members of society – perpetuating distributional, procedural, and recognitional inequity (Nesbitt et al. 2018).

The above paragraphs describe how the various elements of justice interact to form unjust societies. As critical urban geographers have shown, social relations are often mediated by political economy and circuits of capital, reified over time in the urban environment. As shown in chapter Five, inequalities in access to green space can be explained by these forces through formalized housing tenure patterns, bad urban planning, and noxious land uses decisions which negatively impact some residents more than others. These layers of social and environmental relations are complex. In order to help guide wise policy and planning decisions, researchers need to better understand the various factors and forces which either mitigate or multiply green space inequity. We need a conceptual framework that uses the base structure of environmental justice theory to balance the forces and factors which lead to urban green space inequality. A few models have been proposed that present various aspects of green space, for example, its general spatial provision (Boulton, Dedekorkut-Howes, and Byrne 2018), its planning and recreational services (He, Yi, Liu 2016), and its green infrastructural functions and human health (Tzoulas et al. 2007). A conceptual model that captures procedural justice elements is presented by Grove et al. (2018). Based on their work with the Long Term Ecological Research station in Baltimore, it presents the patterns and processes of urban park provision with historical and current environmental injustices.

The conceptual framework I propose here has the force and weight of green space inequality counterbalanced against the force and weight of green space equality (Figure 36). At the base are three relevant dimensions of environmental justice: distribution, procedure, and recognition. Four spatial scales of influence are shown: international, national, state/regional, and local. At the top are international agencies and non-state capital markets which are prime factors in setting development goals and monetary policy. Lower down are national actors, processes, and discourses which interact with and translate policies to the lower scales. Below the national level, there is a mix of state and regional agendas, legislation, and policy which are framed by markets above and below. These agendas are tied to international and local boom-bust economic cycles, prone to windfalls one year and funding shortages the next. At the city scale, mayoral offices, equity-oriented urban planning and community development departments, along with sustainability programs, can counterbalance the "green growth machine" of speculative real estate development and neighborhood gentrification. At the bottom are grassroots organizations and community groups who fight, block by block, for environmental and community justice.

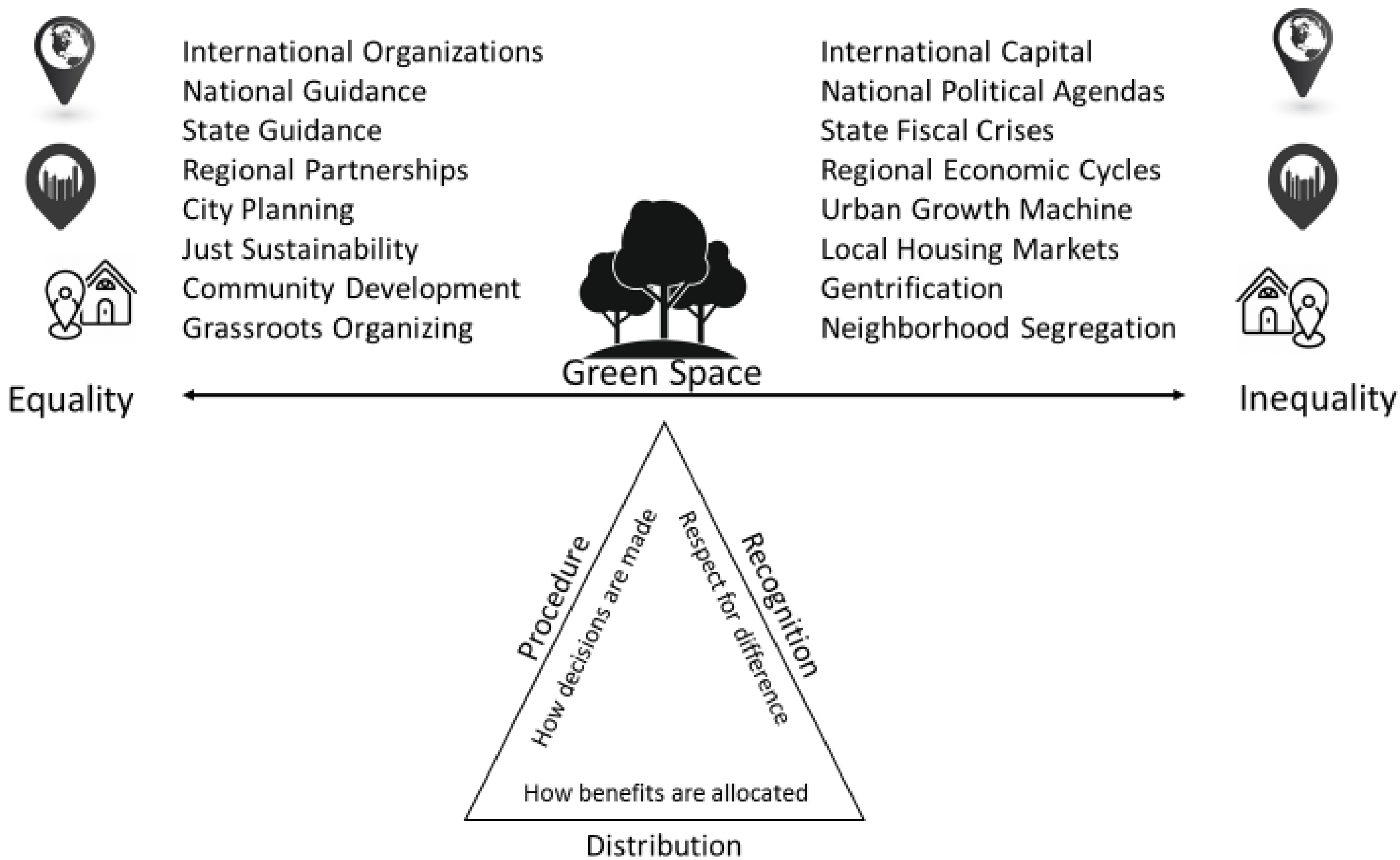


Figure 36 - Conceptual model of the factors that shape urban green space inequality

Elements listed in each box represent the action or force of factors that interact to tilt the line one way or the other. All the elements, regardless of which side they tilt the balance, are prone to “justice gaps”. According to Dawson, Coolsaet, and Martin (2018), justice gaps exist between global environmental governance schemes and local communities; they are mainly due to implementation deficiencies and normative differences. Implementation difficulties are caused by problems of subsidiarity, which is a principle of political and social organization where higher-level authority should be subordinate to local level authority. In the context of urban green space, justice gaps may arise during the creation and allocation of urban green space due to mismatches between what the city wants and what the neighborhood wants. Normative differences also lead to justice gaps. Actors involved have different ideas about what their role is in providing justice and equality, leading to differences in what they think should be done and how. Regardless of those differences, we owe it to each other for all perspectives to be heard when making urban green space decisions. In other words,

> addressing diverse equity concerns from multiple perspectives requires not only financial and human resources to implement equity principles but perhaps, more importantly, a change of thinking allowing dominant discourses to be challenged to the extent that persistent, entrenched injustices may be addressed (Dawson, Coolsaet, and Martin (2018).

In order to tip the balance toward more just and equitable manifestations of urban green space, the environmental justice base values of distribution–procedure–recognition can, and should, be incorporated into people’s perspectives and the institutions who make decisions about the allocation, quality, and ecosystem services provided by urban green spaces.

Conclusion

This dissertation was motivated by the apparent disparities between various racial, social and economic groups and their access to urban green space. This research showed that urban green space inequality patterns do exist in the Denver Metropolitan Area and are caused by historical and social circumstances. My hope is that the results from this dissertation project will help shine a light on urban green space equity and guide future green space planning.

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Chapter Eight: Appendices

Appendix A: "Inequality" and "Inequity"

In recent years, the idea of inequality has vaulted to the front of public debate. Cable news stories about economic inequality and the 1% abound, as do political campaign speeches about healthcare inequality. Sometimes the term "inequity" is used as well. The two terms can be confusing, but there are clear differences between them. To flesh out the differences, let's first look at the definitions of "equality" and "equity".

According to multiple dictionaries (Table A below) equality is simply the state of being equal. This entails "a correspondence in quantity, degree, value, rank or ability" (dictionary.com). Some dictionaries add a justice-specific definition, such as "The right of different groups of people to receive the same treatment" and "The state of being equal, especially in status, right, and opportunities" (Oxford). Equity has a different meaning. None of the dictionaries I referenced had the same definition, but most referred to the quality of being fair or just or impartial. Merriam-Webster takes this a step further and mentions natural law and freedom from bias or favoritism. The term "inequality" has the lengthiest and most complicated definitions. As you can see from the table, most definitions start with the condition of being unequal in an abstract way, but then go into social topics such as disparity, distribution, opportunity, treatment, injustice, and the like. In contrast, "Inequity" has much shorter definitions and is easier to define than "inequality". It is simply an unfair circumstance or an instance of injustice; dictionary.com adds the terms "favoritism" and "bias".

Table A - Definitions

	Equality	Equity	Inequality	Inequity
Merriam - Webster	The quality or state of being equal	Justice according to natural law or right, specifically, the freedom from bias or favoritism	The quality of being unequal or uneven; such as a) social disparity, b) disparity of distribution or opportunity; c) lack of evenness	Injustice; unfairness. An instance of injustice or unfairness
Oxford	The state of being equal, especially in status, rights, and opportunities	The quality of being fair and impartial	Difference in size, degree, circumstances, etc.; lack of equality.	Lack of fairness or justice
Dictionary. com	The state or quality of being equal; correspondence in quantity, degree, value, rank, or ability	The state or quality of being just and fair	The condition of being unequal; lack of equality; disparity; social or economic disparity; unequal opportunity or treatment resulting from this disparity; injustice	Lack of equity; unfairness; favoritism or bias. An unfair circumstance or proceeding
Cambridge	The right of different groups of people to receive the same treatment	The situation in which everyone is treated fairly and equally	The unfair situation in society when some people have more opportunities, money, etc. than other people	The fact that a situation is not fair, or something that is not fair in a situation

The terms "inequality" and "inequity" appear to overlap, but the difference is clear. Inequality is a quantitative measure, while inequity is a qualitative measure. Inequity means injustice or unfairness, while inequality does not necessarily imply an injustice – it is simply an imbalance. However, the way this works in real life is that inequities often lead to inequalities, i.e. situations that are unfair often lead to imbalances. It's important to note that an inequality need not be unfair, but in many social circumstances, they are.

As an illustration, take the well-known image by Angus Maguire with the Interaction Institute for Social Change (Figure A). The image shows three people standing behind a fence looking into a baseball game. The first panel shows three people of different heights each standing on a box. This represents equality since all of them have boxes of the same height. However, this doesn’t necessarily promote fairness or justice, since it doesn’t let everyone watch the game. This is where equity comes in. Equity does not mean giving everyone the same thing, but rather giving them what they need to enjoy the same things as everyone else. As seen in the illustration, the taller person can already see in the game and doesn’t need a box. The shortest person, who couldn’t see the game with a single box, now has two. To put it another way, in the first image, it is assumed that everyone will benefit from the same supports. They are being treated equally. In the second image, individuals are given different supports to make it possible for them to have equal access to the game. They are being treated equitably. Equity is about recognizing that fairness is not distributed evenly, that institutional and systemic barriers exist, and it is society’s responsibility to create access and opportunities that benefit all.

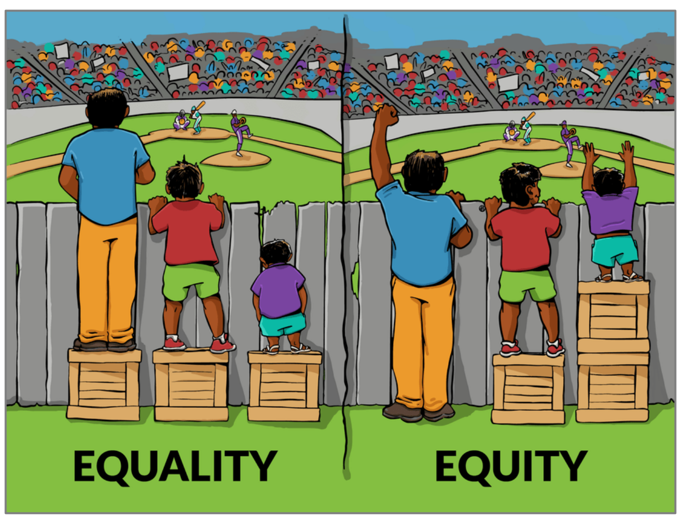


Figure A - Equality vs. Equity

The working hypothesis for my dissertation is that green space distribution is indicative of urban inequalities produced by social inequities. According to the definitions outlined above, inequality is simply the condition of being unequal or uneven. With respect to societies, social inequality refers to the uneven distribution of resources. This typically occurs through norms of allocation such as income, education, ethnicity, etc. They can all be measured quantitatively. Social inequity refers to unfair, avoidable differences arising from poor governance, corruption, or racial biases. The first questions in my dissertation are quantitative in nature. I want to find out if green space ecosystem services are evenly distributed; if they are correlated with demographic characteristics such as income; and which types of ecosystem services are prevalent in rich neighborhoods versus poor neighborhoods. These are ultimately quantitative questions.

A multitude of background evidence suggests that predominately White, wealthy neighborhoods in U.S. cities have access to more green space than non-White, poor neighborhoods (Wolch et al. 2014; Rigolon 2016). In these situations, green space acts as a multiplier of inequality because research has shown that more neighborhood green space amenities lead to higher home prices (Tyryainen 1997; Kong et al. 2007). The concept of equity, i.e. fairness and justice, will be taken up throughout the dissertation, as I discuss policies and practices that have led to inequalities. In the final chapter, I will address urban green space equity directly.

Appendix B: 2019 Census Data for Denver, Lakewood, and Aurora

Category	United States	Denver	Lakewood	Aurora
Population, percent change - April 2010 to July 2018	6.00%	19.50%	9.90%	15.20%
Persons under 5 years, percent	6.10%	6.30%	5.10%	7.10%
Persons under 18 years, percent	22.40%	20.20%	18.90%	25.70%
Persons 65 years and over, percent	16.00%	11.40%	15.90%	10.80%
Female persons, percent	50.80%	49.90%	50.60%	50.70%
Black or African American alone, percent	13.40%	9.40%	1.40%	16.00%
American Indian and Alaska Native alone, percent	1.30%	1.00%	0.90%	0.90%
Asian alone, percent	5.90%	3.80%	3.30%	6.30%
Native Hawaiian and Other Pacific Islander alone, percent	0.20%	0.10%	0.00%	0.30%
Two or More Races, percent	2.70%	3.60%	3.10%	5.40%
Hispanic or Latino, percent	18.30%	30.30%	23.10%	28.40%
White alone, not Hispanic or Latino, percent	60.40%	53.70%	69.40%	45.00%
Foreign born persons, percent	13.50%	15.60%	9.40%	19.90%
Owner-occupied housing unit rate	63.80%	49.60%	58.20%	59.00%
Median value of owner-occupied housing units	$204,900	$357,300	$333,400	$259,000
Median selected monthly owner costs -with a mortgage	$1,558	$1,707	$1,654	$1,529
Median selected monthly owner costs -without a mortgage	$490	$470	$482	$458
Median gross rent	$1,023	$1,217	$1,249	$1,241
Persons per household	2.63	2.31	2.3	2.82
Language other than English spoken at home, persons age 5 years+	21.50%	26.50%	16.10%	32.80%
High school graduate or higher, percent of persons age 25 years+	87.70%	87.10%	91.90%	87.10%

Bachelor's degree or higher, percent of persons age 25 years+	31.50%	47.90%	39.10%	29.10%
With a disability, under age 65 years, percent	8.60%	6.50%	6.50%	7.10%
Persons without health insurance, under age 65 years, percent	10.00%	11.40%	9.80%	12.90%
In civilian labor force, total, percent of population age 16 years+	62.90%	71.60%	69.10%	70.90%
In civilian labor force, female, percent of population age 16 years+	58.20%	66.40%	64.50%	65.10%
Total retail sales per capita, 2012	$13,443	$11,212	$17,377	$12,081
Mean travel time to work (minutes), workers age 16 years+	26.6	25.4	26.5	29.7
Median household income (in 2018 dollars)	$60,293	$63,793	$64,100	$62,541
Per capita income in past 12 months (in 2018 dollars)	$32,621	$41,196	$36,835	$28,854
Persons in poverty, percent	11.80%	13.80%	9.60%	12.00%
Population per square mile, 2010	87.4	3,922.60	3,334.40	2,100.90
Land area in square miles, 2010	3531905	42.88	42.88	154.73

Appendix C: Data Collection Sheet Examples

Name of green space	Bear Creek Park	Notes:
Municipality	Denver	
Address	3550 S Raleigh St, Denver, CO 80236	

Green Space Name		General Notes:
Name		
Day		
Time		
Weather conditions		

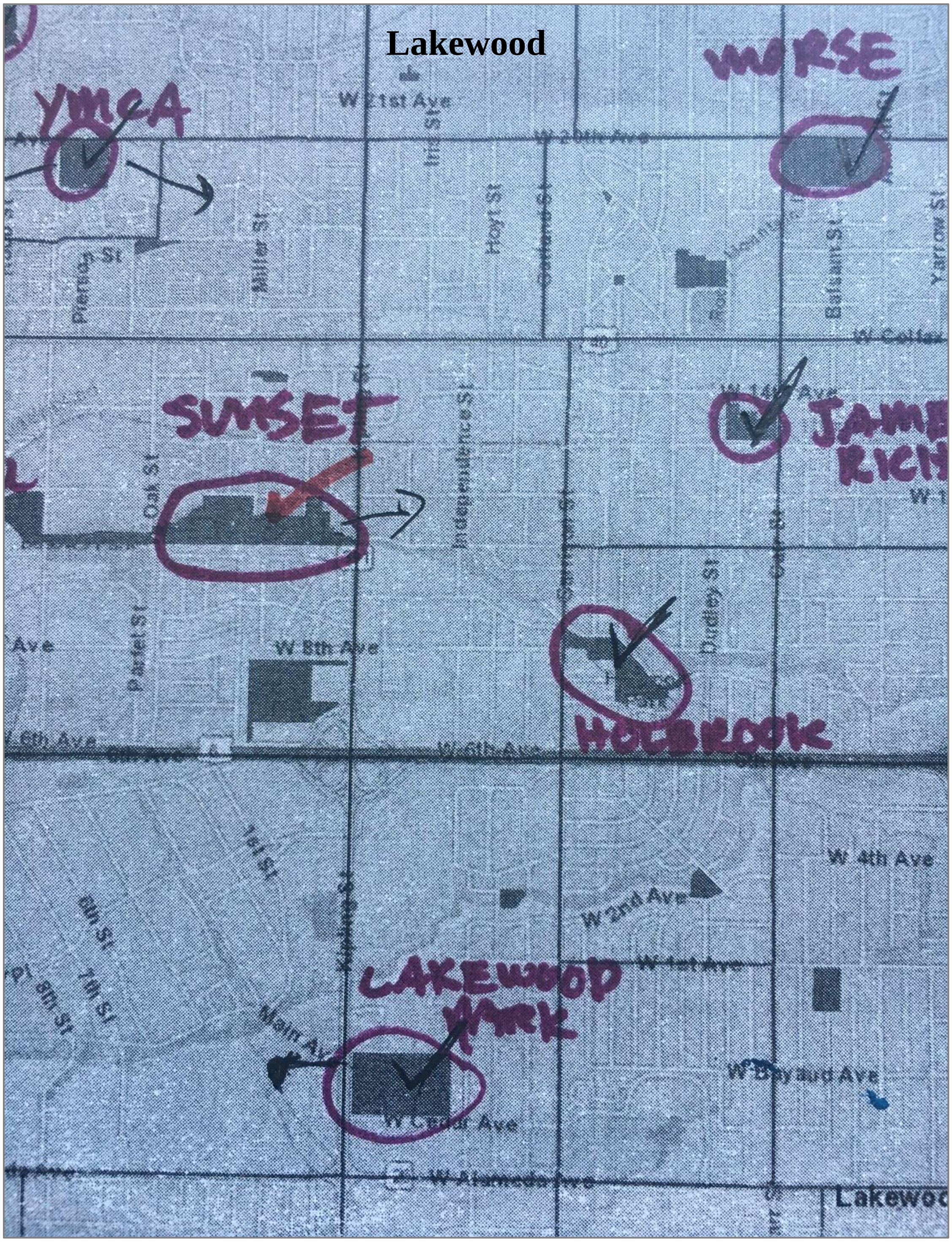
Vegetation Sampling		Notes:
	# of Species*	
Transect 1 (10 paces)		
Transect 2 (10 paces)		*Number of different plant species (grass, shrubs, trees) inside transect.

Green space users		Notes:
# of users visible		
What activities are they doing?		

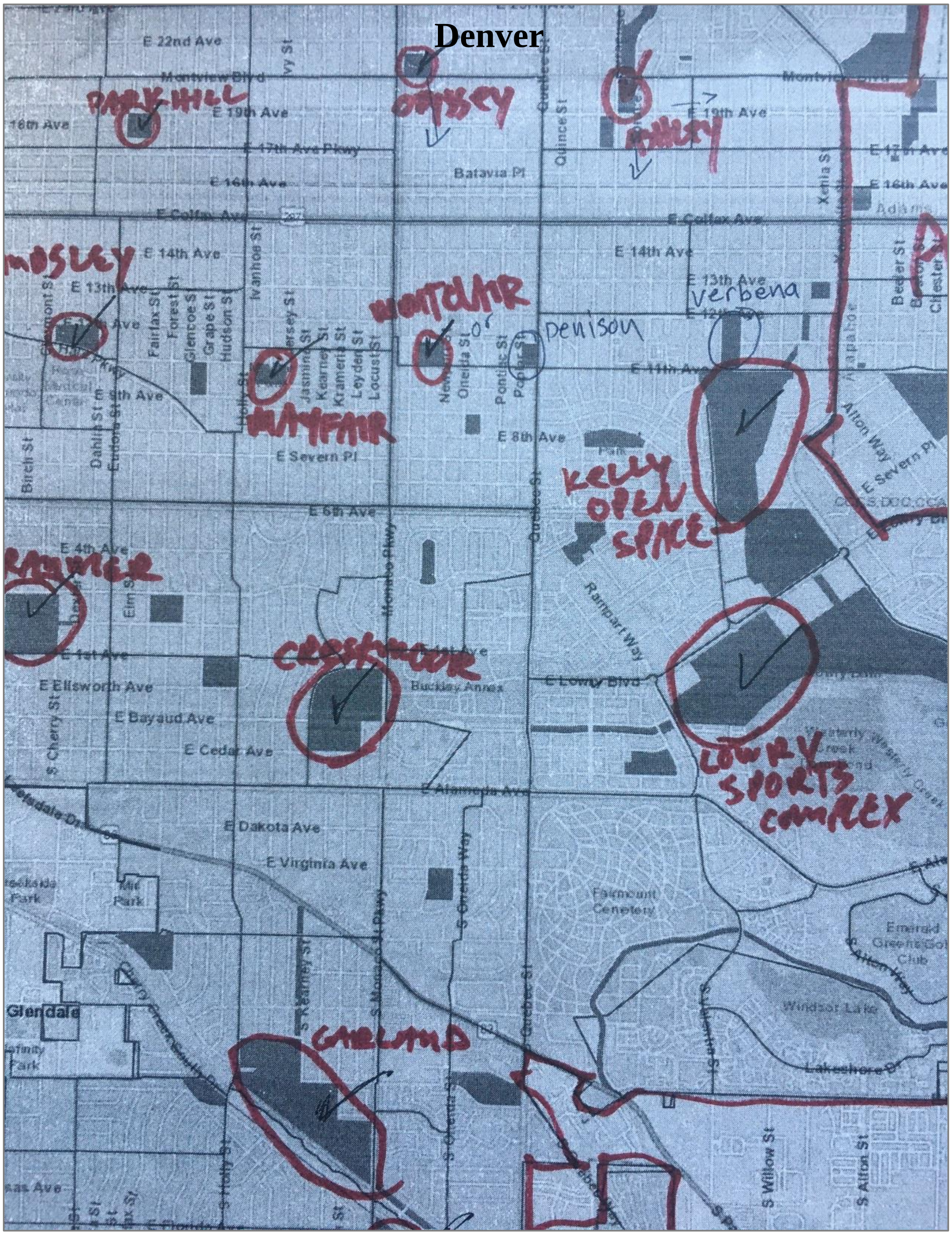
Crops		Notes:
	Yes or no*	
Community gardens or farming activities?		* If "Yes", Josh will collect GIS data later.

Cultural Resources		Notes:
# of resources		
Type of resource (historical, religious, educational, artistic)		

Appendix D: Examples of Selected Green Spaces

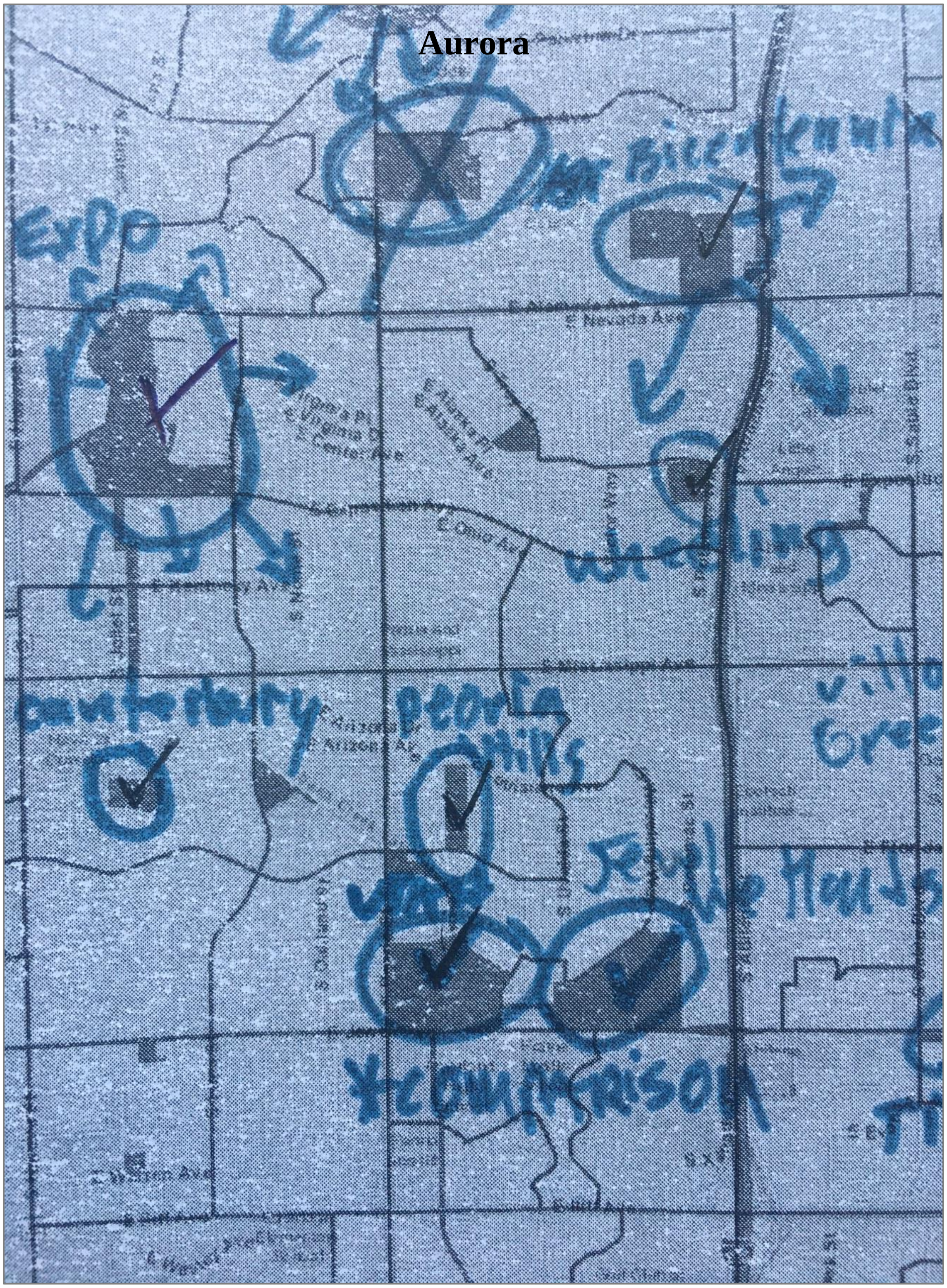


Denver

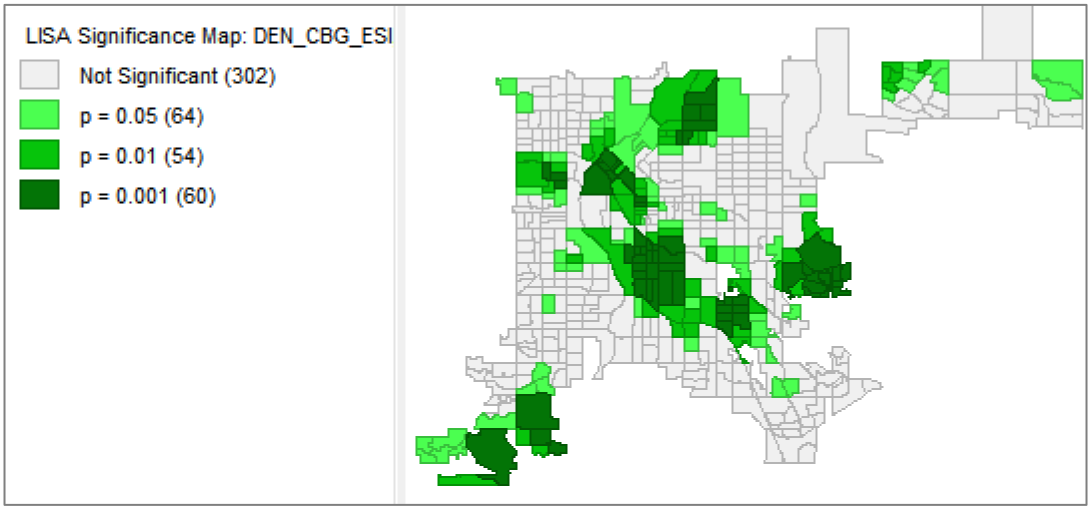


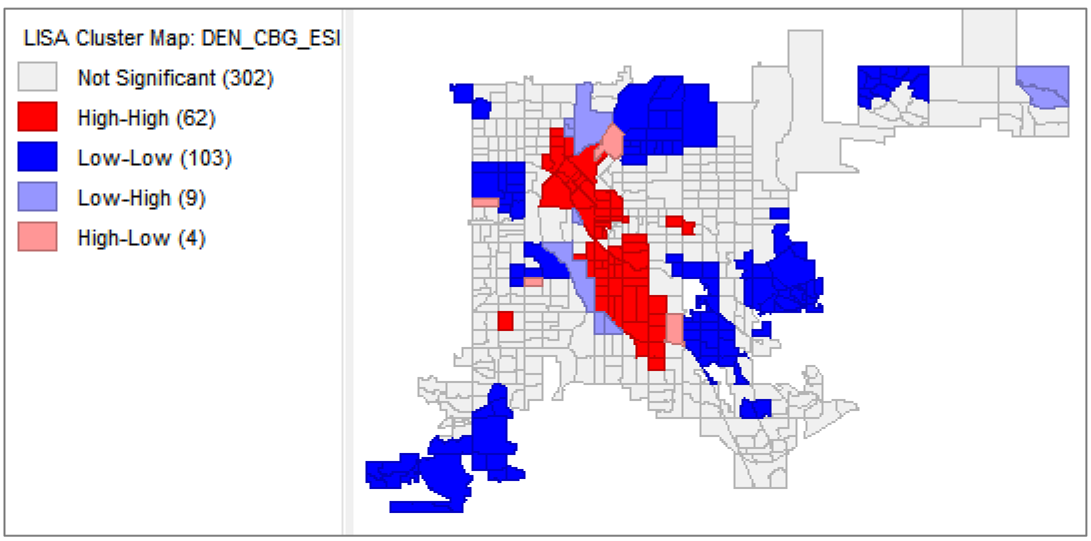
PARK HILL
ODYSSEY
MOSLEY
MONTCLAIR
or
Denison
Verbena
MAYFAIR
KELLY OPEN SPACE
CRESTMOOR
LOWRY SPORTS COMPLEX
E 22nd Ave
Montview Blvd
E 19th Ave
E 17th Ave Pkwy
E 16th Ave
Batavia Pl
E Colfax Ave
E 14th Ave
E 13th Ave
E 11th Ave
E 8th Ave
E Severn Pl
E 6th Ave
E 4th Ave
E 1st Ave
E Ellsworth Ave
E Bayaud Ave
E Cedar Ave
Buckley Annex
E Lowry Blvd
E Alameda Ave
E Dakota Ave
E Virginia Ave
Fairmount Cemetery
Rampart Way
Quebec St
Quince St
Monaco Pkwy
Glendale
Windsor Lake
Lakeshore Dr
Emerald Greens Golf Club
S Willow St
S Alton St

Aurora



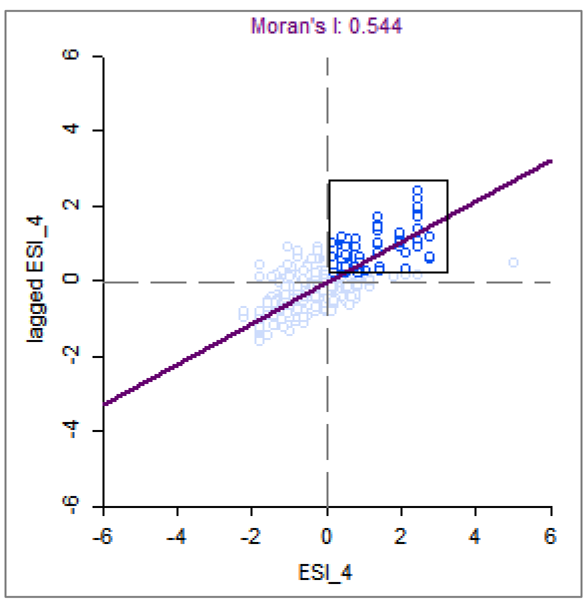
Appendix E: Exploratory Data Analysis of Denver, Colorado





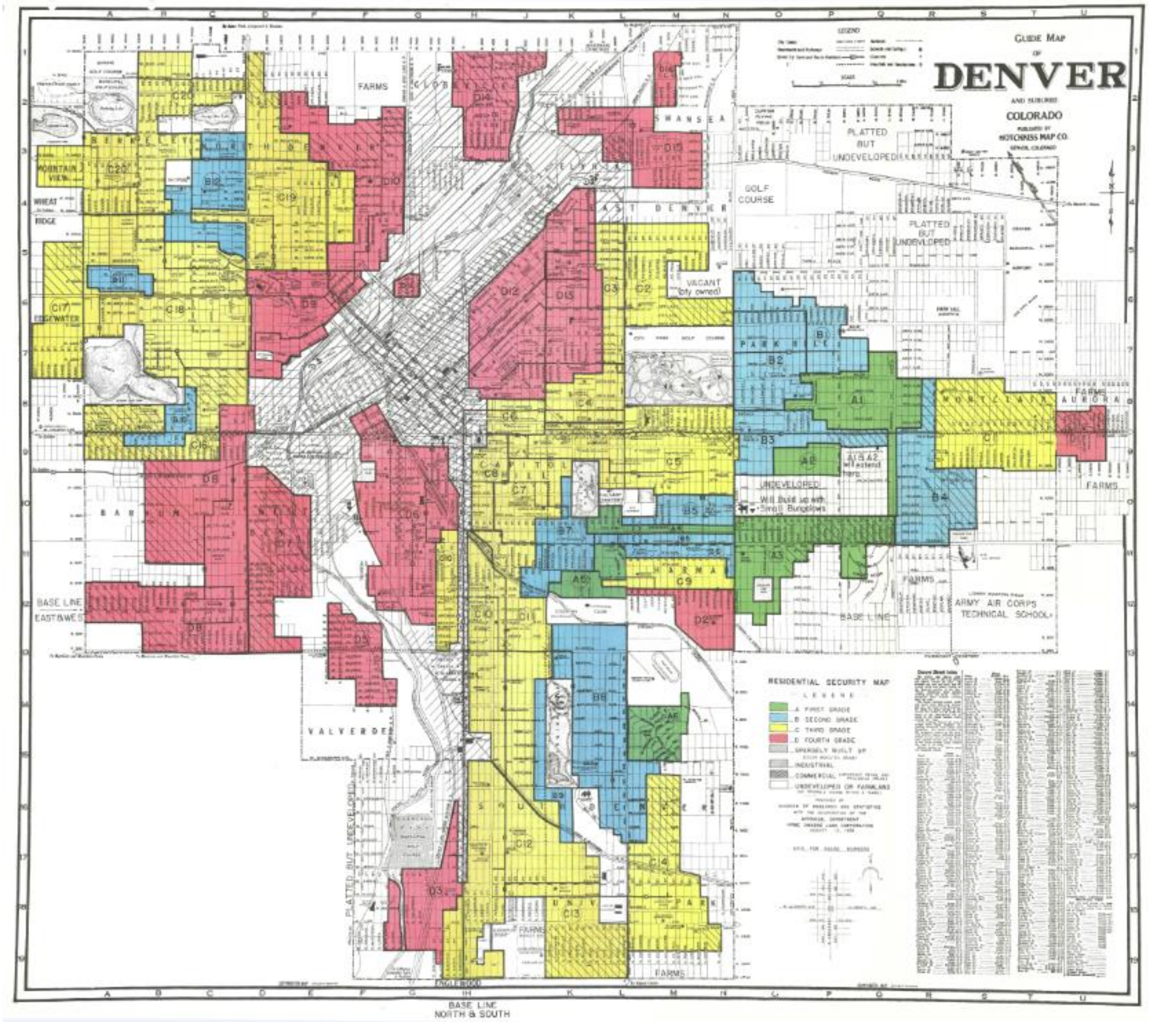
The above images are the Local Moran's I Significance Map and Cluster Map for the ecosystems service index scores of Denver's census block groups. This type of test for spatial association, also known as spatial autocorrelation, is designed so that a null hypothesis of no spatial autocorrelation (a random spatial pattern) is rejected if large values are consistently surrounded by large values, if small values are consistently surrounded by small values, or if large values are surrounded by both small values and large values (Anselin 1995; Talen 1997).

The significance map shows census block groups that are statistically clustered, with the degree of significance reflected in increasingly darker shades of green. The map starts with $p < 0.05$ and shows all the categories of significance that are meaningful for the given number of permutations. The local indicators of spatial association "LISA" map provides information on the relative importance of spatial association: high values (above the mean) associated with high neighboring values, and low values (below the mean) associated with low neighboring values. Only the blocks with statistically significant values are shown in the map. The cluster map augments the significance map by representing the type of spatial association, based on the location of the value and its spatial lag in the Moran scatter plot (below).



Four categories are represented in the cluster map, with dark red for the high-high clusters (central and south Denver), dark blue for the low-low clusters (scattered around the edges of Denver), light blue for the low-high spatial outliers, and light red for the high-low spatial outliers. The values in the upper-right quadrant of the scatter plot (the data points inside the box) represent the high-high red census block groups which are clustered in central Denver.

Appendix F: Home Owner Loan Corporation Maps and Documents



NS FORM 8
10-1-37

AREA DESCRIPTION - SECURITY MAP OF Denver, Colorado

1. AREA CHARACTERISTICS:
   a. Description of Terrain. Rolls slightly in southern part, a hill around Alameda.
   b. Favorable Influences. Washington Park, South High School, nearby Denver University, Grade Schools, adequate transportation - all utilities.
   c. Detrimental Influences. None outstanding.
   d. Percentage of land improved 85 %; e. Trend of desirability next 10-15 yrs. Static
2. INHABITANTS:
   a. Occupation Business, professional, white collared clerical; b. Estimated annual family income $ 1800-4500
   c. Foreign-born families 0 %; ______ predominating; d. Negro 0 ; ___ %
   e. Infiltration of Above class; f. Relief families Few
   g. Population is increasing Yes; decreasing -; static -
3. BUILDINGS:

	PREDOMINATING 100 %		OTHER TYPE %		OTHER TYPE %	
a. Type	Singles					
b. Construction	Brick					
c. Average Age	16 Years		Years		Years	
d. Repair	Good					
e. Occupancy	99 %		%		%	
f. Home ownership	64 %		%		%	
g. Constructed past yr.	10-12					
h. 1929 Price range	$ 4250-25,000	100%	$	100%	$	100%
i. 1937 Price range	$ 3500-18,000	75%	$	%	$	%
j. 1938 Price range	$ 3500-18,000	72%	$	%	$	%
k. Sales demand	$ Up to $6500		$		$	
l. Activity	Good					
m. 1929 Rent range	$ 35 - 85	100%	$	100%	$	100%
n. 1937 Rent range	$ 30 - 65	80%	$	%	$	%
o. 1938 Rent range	$ 30 - 65	80%	$	%	$	%
p. Rental demand	$ Up to $50		$		$	
q. Activity	Good					

4. AVAILABILITY OF MORTGAGE FUNDS: a. Home purchase Ample; b. Home building Ample
5. CLARIFYING REMARKS: This large area is very spotty, with a wide variety of houses. The 4 blocks south of Kentucky, fringing on Washington Park, too small to grade separately, is built up with very high grade structures valued up to $18,000. That portion to the north, adjoining Country Club, is similar in character to parts of A-5, but is built up and will decline because of age. It is a brick bungalow area with some cottages in the southeast portion. Washington Park and South High School, as well as nearby Denver University, are distinctly favorable influences. This should be a good area for some years to come. It is the heart of section referred to as "South Denver" where values held up reasonably well.
6. NAME AND LOCATION Denver, Colorado SECURITY GRADE B AREA NO. 8

NS FORM 8
10-1-37

AREA DESCRIPTION - SECURITY MAP OF Denver, Colorado

1. AREA CHARACTERISTICS:
   a. Description of Terrain. Level.

   b. Favorable Influences. Washington Park - Schools - adequate transportation - all utilities.

   c. Detrimental Influences. None outstanding.

   d. Percentage of land improved 98 %; e. Trend of desirability next 10-15 yrs. Static to down

2. INHABITANTS:
   a. Occupation Business, professional, clerks; b. Estimated annual family income $ 1800-3500
   c. Foreign-born families 0 %; ______ predominating; d. Negro 0 ; ___ %
   e. Infiltration of Above class ; f. Relief families Very few
   g. Population is increasing - ; decreasing - ; static Yes

3. BUILDINGS:

	PREDOMINATING 100 %		OTHER TYPE %		OTHER TYPE %	
a. Type	Singles					
b. Construction	Brick					
c. Average Age	20 Years		Years		Years	
d. Repair	Good					
e. Occupancy	98 %		%		%	
f. Home ownership	50 %		%		%	
g. Constructed past yr.	None					
h. 1929 Price range	$ 5500-18,000	100%	$	100%	$	100%
i. 1937 Price range	$ 4500-10,000	75 %	$	%	$	%
j. 1938 Price range	$ 4500-10,000	72 %	$	%	$	%
k. Sales demand	$ Up to $8,000		$		$	
l. Activity	Poor					
m. 1929 Rent range	$ 50 - 80	100%	$	100%	$	100%
n. 1937 Rent range	$ 40 - 65	75 %	$	%	$	%
o. 1938 Rent range	$ 40 - 65	75 %	$	%	$	%
p. Rental demand	$ Up to $55		$		$	
q. Activity	Good					

4. AVAILABILITY OF MORTGAGE FUNDS: a. Home purchase Ample; b. Home building Ample

5. CLARIFYING REMARKS: The fact that this area borders on Washington Park, with a substantial type of good bungalows, sets it out from the surrounding 3rd grade sections. There is a definite break between Corona and Ogden, in the type of houses. The Park is the principal reason why this area has maintained its character. A fair "B" section.

6. NAME AND LOCATION Denver, Colorado SECURITY GRADE B AREA NO. 9

D15: Elyria Swansea

NS FORM 8
10-1-37

AREA DESCRIPTION - SECURITY MAP OF Denver, Colorado

1. AREA CHARACTERISTICS:
   a. Description of Terrain. Level.

   b. Favorable Influences. Adequate transportation - schools, utilities.

   c. Detrimental Influences. Unpaved streets - stench from stockyards and packing plants west of the area.

   d. Percentage of land improved 60 %; e. Trend of desirability next 10-15 yrs. Static

2. INHABITANTS:
   a. Occupation Wage earners ; b. Estimated annual family income $ Up to $1500

   c. Foreign-born families 20 %; Southern European predominating; d. Negro Few ; %

   e. Infiltration of Wage earners ; f. Relief families About 70

   g. Population is increasing - ; decreasing - ; static Yes

3. BUILDINGS:

	PREDOMINATING 100 %		OTHER TYPE %		OTHER TYPE %	
a. Type	Singles		(Few doubles)			
b. Construction	Frames, few brick					
c. Average Age	36 Years		Years		Years	
d. Repair	Fair to poor					
e. Occupancy	98 %		%		%	
f. Home ownership	52 %		%		%	
g. Constructed past yr.	1 or 2					
h. 1929 Price range	$ 1250-4500	100%	$	100%	$	100%
i. 1937 Price range	$ 750-4000	75%	$	%	$	%
j. 1938 Price range	$ 750-4000	70%	$	%	$	%
k. Sales demand	$ Poor		$		$	
l. Activity	Poor					
m. 1929 Rent range	$ 12.50-32.50	100%	$	100%	$	100%
n. 1937 Rent range	$ 10 - 27.50	80 %	$	%	$	%
o. 1938 Rent range	$ 10 - 27.50	80 %	$	%	$	%
p. Rental demand	$ Up to 22.50		$		$	
q. Activity	Good					

4. AVAILABILITY OF MORTGAGE FUNDS: a. Home purchase Limited ; b. Home building Limited

5. CLARIFYING REMARKS: An area occupied entirely by industrial workers from the packing plants, stockyards to the west and other plants nearby. It has a wide range and variety of houses from cheap frames to some fair bungalows. Many are ill kept, with outside toilets. Real estate men pay little attention to the area. Demand for homes is entirely by wage earners of the low income brackets, who do not mind the stench from the stockyards district. A fair "D".

6. NAME AND LOCATION Denver, Colorado SECURITY GRADE D AREA NO. 15

NS FORM 8
10-1-37

AREA DESCRIPTION - SECURITY MAP OF Denver, Colorado

1. AREA CHARACTERISTICS:
   a. Description of Terrain. Level.

   b. Favorable Influences. Utilities - adequate transportation - fair school facilities.

   c. Detrimental Influences. Stench from packing plants - lack of improvements.

   d. Percentage of land improved 75 %; e. Trend of desirability next 10-15 yrs. Static to down

2. INHABITANTS:
   a. Occupation Wage earners ; b. Estimated annual family income $ Up to $1200

   c. Foreign-born families 10 %; Mixture predominating; d. Negro 0 ; %

   e. Infiltration of Laborers ; f. Relief families About 30

   g. Population is increasing ; decreasing ; static Yes

3. BUILDINGS:

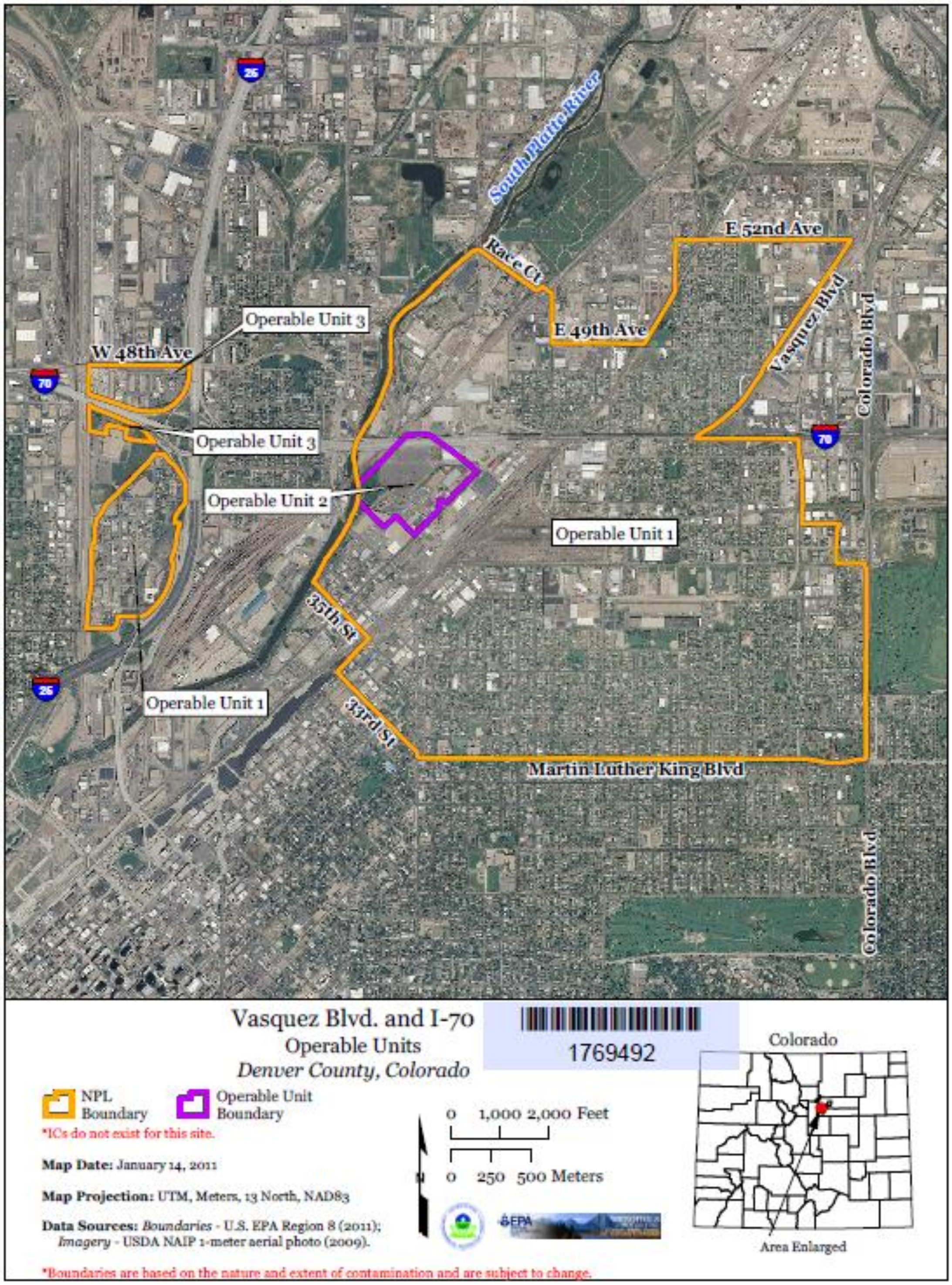
	PREDOMINATING 100%		OTHER TYPE %		OTHER TYPE %	
a. Type	Single					
b. Construction	Frame (few brick)					
c. Average Age	36 Years		Years		Years	
d. Repair	Fair to poor					
e. Occupancy	98 %		%		%	
f. Home ownership	52 %		%		%	
g. Constructed past yr.	None					
h. 1929 Price range	$ 450-3800	100%	$	100%	$	100%
i. 1937 Price range	$ 300-3000	73%	$	%	$	%
j. 1938 Price range	$ 300-3000	68%	$	%	$	%
k. Sales demand	$ Up to $1800		$		$	
l. Activity	Fair					
m. 1929 Rent range	$ 15-30	100%	$	100%	$	100%
n. 1937 Rent range	$ 10-25	78%	$	%	$	%
o. 1938 Rent range	$ 10-25	78%	$	%	$	%
p. Rental demand	$ Up to $20		$		$	
q. Activity	Good					

4. AVAILABILITY OF MORTGAGE FUNDS: a. Home purchase Limited ; b. Home building Limited

5. CLARIFYING REMARKS: The security in this area is cheaper than that in nearby D-15. The area is occupied entirely by workers from the packing plants, stockyards and railroad shops. On the northern edge of the city this section is little known to real estate men who pay little or no attention to it. The only demand for property is by low income wage earners who do not mind the stench from the stockyards area. Streets are unpaved. In an undeveloped part of the city, between R. R. tracks, with its small, poorly built houses, the area is a "fair to poor D" typical of any such section near a meat packing industry.

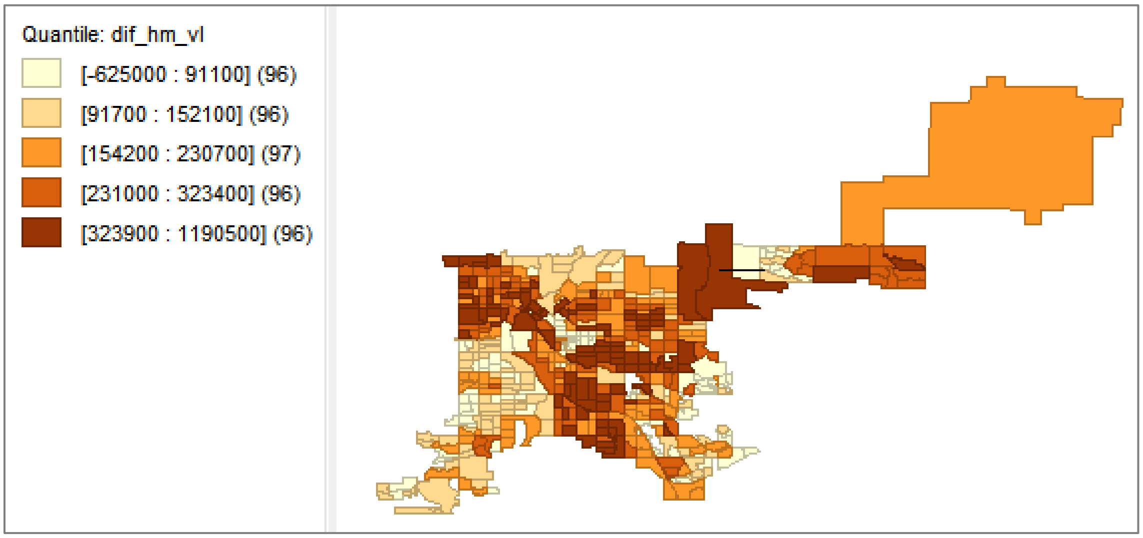
6. NAME AND LOCATION Denver, Colorado SECURITY GRADE D AREA NO. 16

Appendix G: EPA Map of Vasquez Blvd and I-70 Superfund Site

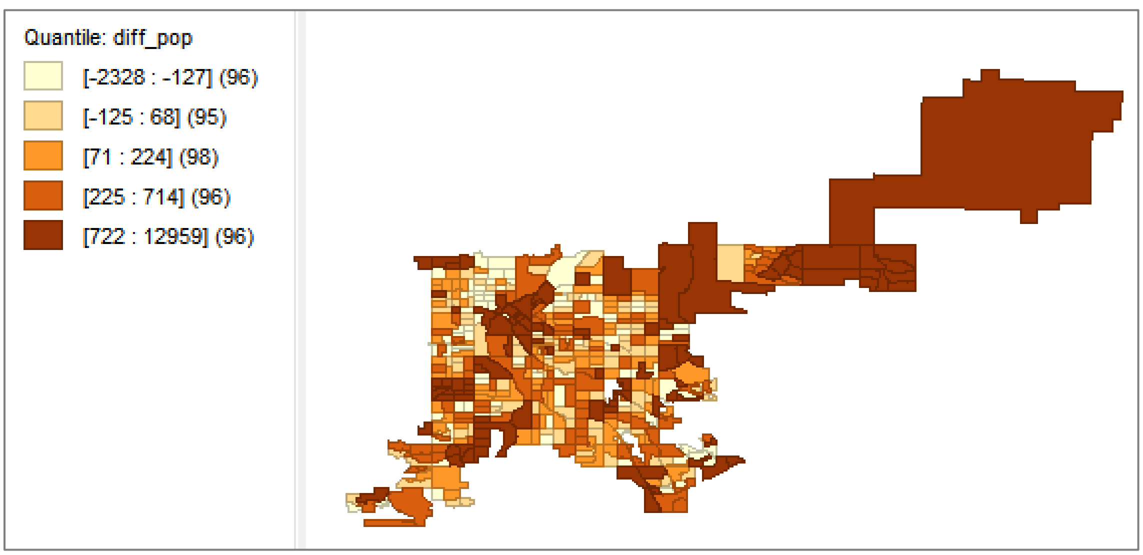


Appendix H: Sociodemographic change maps of Denver, 2000 to 2016

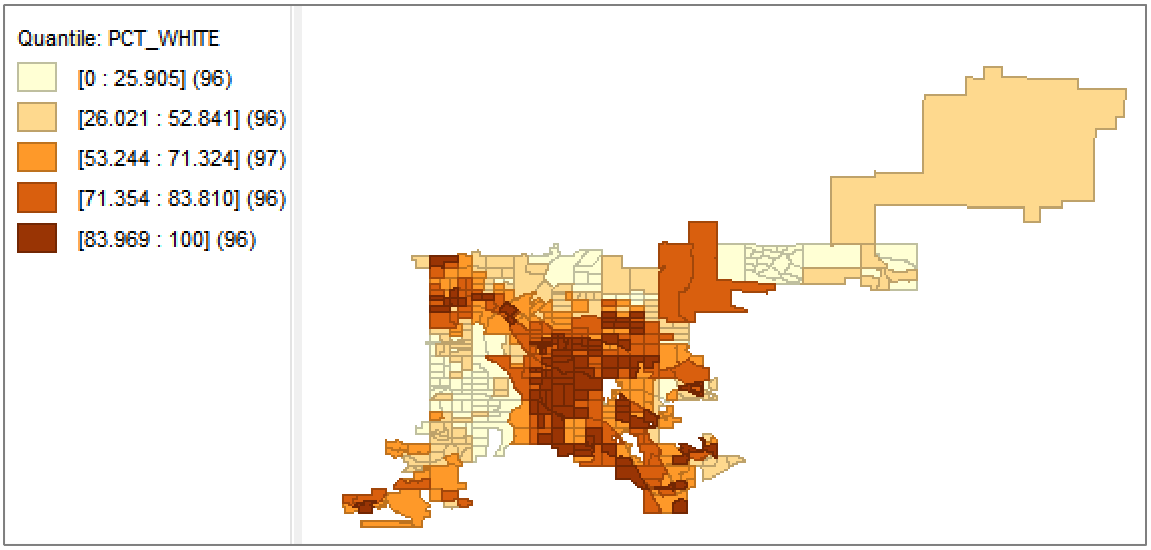
Difference in Home Value 2000 - 2016



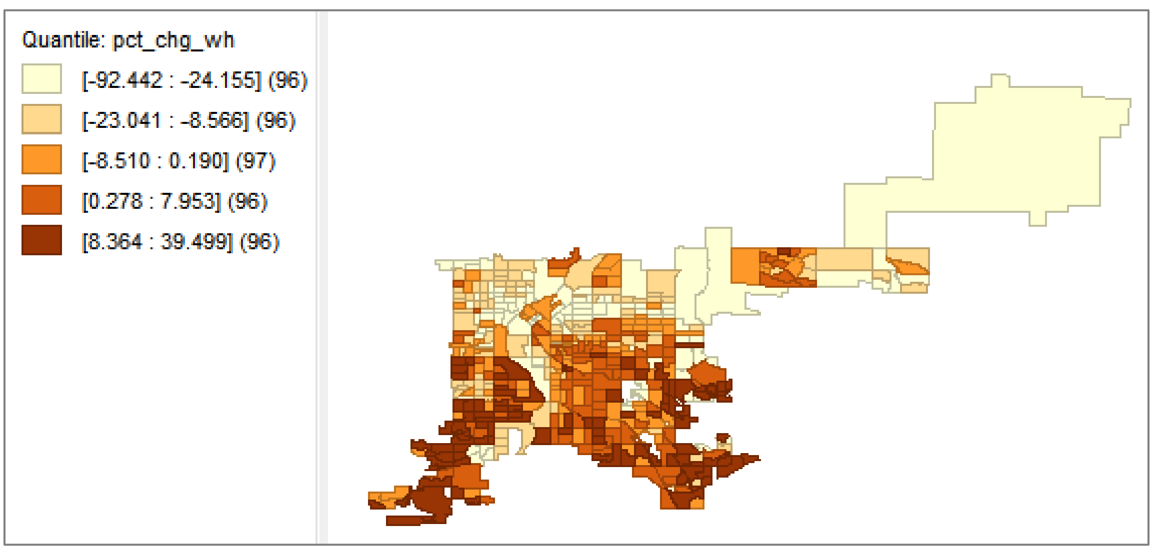
Difference in Population 2000 – 2016



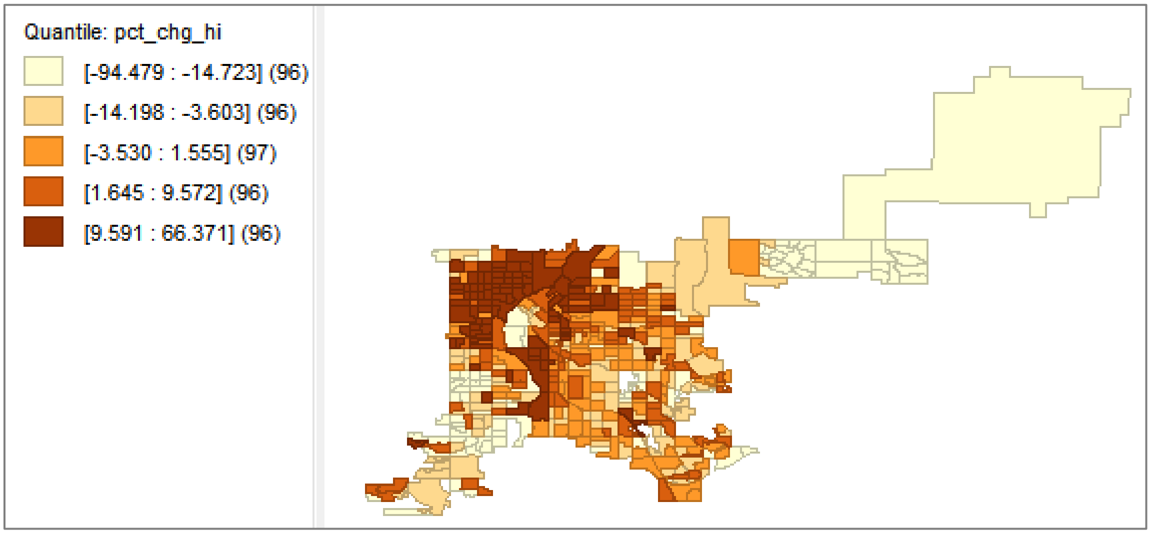
Percent White Population – 2016



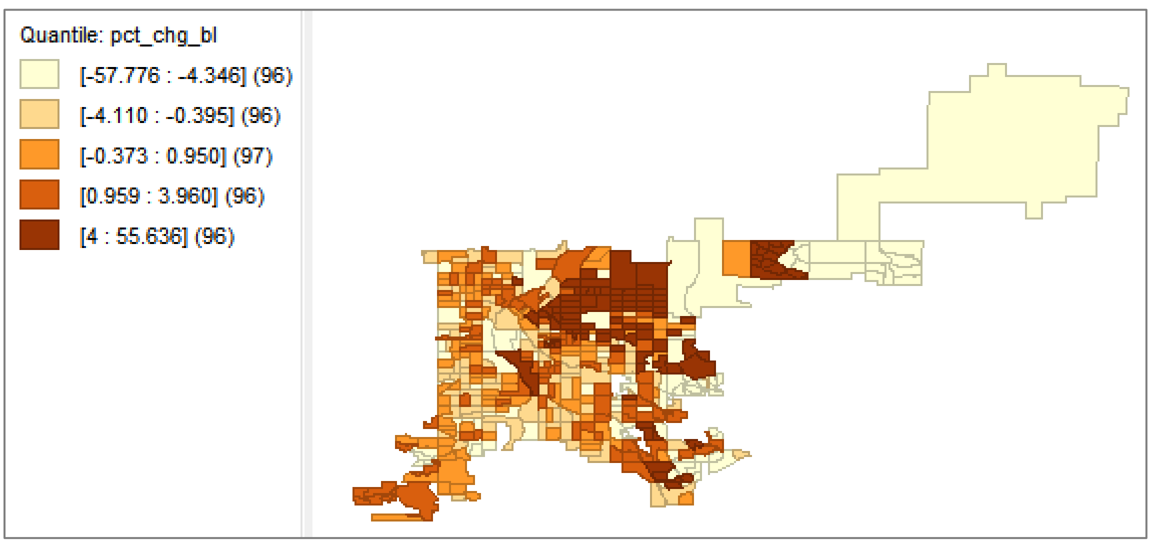
Percent Change White Population 2000 – 2016



Percent Change Hispanic 2016 – 2010



Percent Change Black Population 2000 – 2016



Appendix I: Challenges and opportunities for urban green space governance using an ecosystem services framework

A primary challenge of the ecosystem services framework is integrating it into everyday decisions, into international, state and corporate policy – as well as city planning departments and neighborhood organizations (Daily et al. 2009). The incorporation of the ecosystem services concept in urban planning and policymaking is still nascent (Niemela 2010; Rall, Kabisch, and Hansen 2015). More empirical evidence is needed so that we can gather best practices for green space governance: identifying links among decisions, ecosystems, values, and institutions. Ultimately, effective governance is needed to integrate ecosystem services into the everyday decisions made at city planning departments and neighborhood organizations.

Governance is related to the structures and processes by which people in societies make decisions, share power, and shape collective action (Lebel et al. 2006). It includes formal institutions such as laws and regulations, as well as informal interactions among people and groups through norms, debates, negotiations, protests, and other decision-making processes. It emerges through interactions of many actors, including private, public, and non-profit entities (Lebel et al. 2006). Governance is a manifestation of human values, a reflection of how we want to behave and interact with each other and the world. At the same time, it can only be as effective as it is designed to be. In fact, governance failures are the cause of many social and natural resource management problems (Scott 1998; Pahl-Wostl 2009). Many resource governance regimes are based on informal guiding principles that can be characterized as a kind of paradigm, which are subject to change over time (Kuhn 1962; Pahl-Wostl 2007). This provides us an opportunity to transition to new governance schemes, ones that incorporate ecosystem services. This will require a great transformation of societies and new social contracts for stewarding the global and local commons (Nakicenovic et al. 2016).

The promise of ecosystem services, as a concept for valuing the economic and cultural benefits of the environment, is coming to a head. A conceptual framework, developed by Gretchen Daily and colleagues (2009), shows how ecosystem services can be integrated into global and local decision-making. Within this framework, institutions are linked in a chain of decisions, ecosystems, services, and values. The authors offer the framework to show the importance of designing effective and long-lasting institutions that can help manage, monitor, and reflect the full values of ecosystem services. Forms of governance that have been studied in various disciplines also show promise in helping integrate ecosystem services into practices. Those include bottom-up strategies for ecosystem services uptake (Rall, Kabisch, and Hansen 2015); adaptive co-management of urban ecosystems (Grove 2009); polycentric governance networks (Lebel et al. 2006); and institutional diversity (Ostrom 1990; Ostrom 2010). All of these should be studied in more depth in order to find the best framework for integration with the ecosystem services concept.

Institutions that become relevant are those that allow value identification and allocation in society (Norgaard 2010; Primmer et al 2016). The most visible "value articulating" institution in society is the market; however, most ecosystem services and benefits are not measurable or tangible, making it difficult to trace their distribution and allocation. As ecological economics points out, the market is rarely the best institution to use when identifying values and when planning the allocation of benefits. The application and development of the ecosystem service concept, if embedded in governance, has the potential to function as a value-articulating institution itself – above the market (Vatn, 2005; Primmer et al. 2015). Indeed, nonmarket and informal institutions such as social and political groups are more likely than market and formal institutions to identify the uneven distribution of benefits, and attempt to re-allocate them (Primmer et al. 2015).

Existing political and economic systems are inadequate for equitably managing public goods and services. This is particularly problematic since many of the services provided by ecosystems are vital, yet undervalued. Numerous wicked environmental problems, such as a) climate change, b) ozone depletion, and c) biodiversity loss could each, in kind, be resolved by strengthening the planet's usual systems that a) naturally regulates the climate, b) protects living things from solar radiation, and c) facilitates biodiversity through trophic interactions and a functional food web. Global initiatives have been established that provide guidance, and sometimes monetary incentives, to help manage wicked problems. However, since many of them involve public goods and services, they have proven, so far, to be beyond market fixes. The ecosystem services framework, by broadening our understanding and appreciation of the ecosystems that sustain life on the planet, could be marshalled as an effective and integrative tool for sustainability, ecosystem management, and policymaking.

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